173

APR 4 1938

Vol. 22, No. 4 April, 1938

PSYCHOLOGICAL REVIEW PUBLICATIONS

Journal of Experimental Psychology

EDITED BY

SAMUEL W. FERNBERGER

UNIVERSITY OF PENNSYLVANIA

CONTENTS

The Effect of Supporting and Antagonistic Voluntary Instructions on Conditioned Discrimination: E. R. HILGARD AND L. G. HUMPHREYS 291

Reinforcement, Extinction, and Spontaneous Recovery in a Non-Pavlovian Reaction: R. E. P. YOUTZ 305

A Study of Backward and Remote Forward Association: M. H. TROWBRIDGE 319

Experimental Studies in Rote-Learning Theory. II. Reminiscence with Varying Speeds of Syllable Presentation: C. I. HOVLAND 338

The Effect of Electric Shock for Right Responses on Maze Learning in Human Subjects: H. GURNEE 354

A New Method for the Uninterrupted Registering of Blood Pressure as a Psycho-Physiological Research Technique for the Study of Psychic Stimuli on the Blood Pressure: B. STOKVIS 365

A Further Investigation of the Role of Emphasis in Learning: E. H. PORTER, JR. AND C. S. HALL 377

The Effect of "Something Happening" after a Response: F. A. COURTS AND D. WAGGONER 383

Subjective Flicker Rate with Relation to Critical Flicker Frequency: S. H. BARTLEY 388

PUBLISHED MONTHLY, TWO VOLUMES PER YEAR

FOR THE AMERICAN PSYCHOLOGICAL ASSOCIATION

BY THE PSYCHOLOGICAL REVIEW COMPANY

PRINCE AND LEMON STS., LANCASTER, PA.

AND OHIO STATE UNIVERSITY, COLUMBUS, OHIO

Entered as second-class matter, July 1, 1920, at the post-office at Lancaster, Pa.

PUBLICATIONS OF

THE AMERICAN PSYCHOLOGICAL ASSOCIATION

WILLARD L. VALENTINE, *Business Manager*

PSYCHOLOGICAL REVIEW

HERBERT S. LANGFELD, *Editor*
Princeton University

Contains original contributions only, appears bi-monthly, January, March, May, July, September, and November, the six numbers comprising a volume of about 540 pages.
Subscription: $5.50 (Foreign, $5.75). Single copies, $1.00.

PSYCHOLOGICAL BULLETIN

JOHN A. MCGEOCH, *Editor*
Wesleyan University

Contains critical reviews of books and articles, psychological news and notes, university notices, and announcements. Appears monthly (10 issues), the annual volume comprising about 720 pages. Special issues of the BULLETIN consist of general reviews of recent work in some department of psychology.
Subscription: $6.00 (Foreign, $6.25). Single copies, 60c.

JOURNAL OF EXPERIMENTAL PSYCHOLOGY

S. W. FERNBERGER, *Editor*
University of Pennsylvania

Contains original contributions of an experimental character. Appears monthly (since January, 1937), two volumes per year, each volume of six numbers containing about 625 pages.
Subscription: $14.00 ($7.00 per volume; Foreign, $7.25). Single copies, $1.25.

PSYCHOLOGICAL ABSTRACTS

WALTER S. HUNTER, *Editor*
Brown University

Appears monthly, the twelve numbers and an index supplement making a volume of about 700 pages. The journal is devoted to the publication of non-critical abstracts of the world's literature in psychology and closely related subjects.
Subscription: $7.00 (Foreign, $7.25). Single copies, 75c.

PSYCHOLOGICAL MONOGRAPHS

JOHN F. DASHIELL, *Editor*
University of North Carolina

Consist of longer researches or treatises or collections of laboratory studies which it is important to publish promptly and as units. The price of single numbers varies according to their size. The MONOGRAPHS appear at irregular intervals and are gathered into volumes of about 500 pages.
Subscription: $6.00 per volume (Foreign, $6.30).

JOURNAL OF ABNORMAL AND SOCIAL PSYCHOLOGY

GORDON W. ALLPORT, *Editor*
Harvard University

Appears quarterly, January, April, July, October, the four numbers comprising a volume of 560 pages. The journal contains original contributions in the field of abnormal and social psychology, reviews, notes and news.
Subscription: $5.00 (Foreign, $5.25). Single copies, $1.50.

COMBINATION RATES

Review and Bulletin: $10.00 (Foreign, $10.50).
Review and J. Exp. (2 vols.): $17.00 (Foreign, $17.75).
Bulletin and J. Exp. (2 vols.): $18.00 (Foreign, $18.75).
Review, Bulletin, and J. Exp. (2 vols.): $22.00 (Foreign, $23.00).

Subscriptions, orders, and business communications should be sent to

THE PSYCHOLOGICAL REVIEW COMPANY

THE OHIO STATE UNIVERSITY, COLUMBUS, OHIO

Journal of
Experimental Psychology

E.E. E.E

VOL. 22, NO. 4 APRIL, 1938

THE EFFECT OF SUPPORTING AND ANTAGONISTIC VOLUNTARY INSTRUCTIONS ON CONDITIONED DISCRIMINATION

BY ERNEST R. HILGARD AND LLOYD G. HUMPHREYS

Stanford University

That knowledge of the stimulus relationships may affect the rate of discrimination was shown in an earlier report on conditioned eyelid discrimination, Experiment III of this series (4).[1] This agrees with several other studies which have indicated the influence of expectancy, attitude, or verbal controls (1) (2) (3) (6) (7). It does not follow that the conditioned responses are under full voluntary control. An analogous instance of the effect of knowledge on relatively non-voluntary responses is found in emotion. A free animal is reacted to more violently than a caged one. The visceral responses are in accordance with information about the dangers in the situation, but they are not thereby strictly voluntary. The present report is concerned with the differences which are found in conditioned discrimination experiments when, in addition to receiving information about the stimuli, the subjects are given instructions to further or to impede the conditioned discrimination.

[1] The series of experiments of which this is Experiment V have been supported by grants to the senior author from the Social Science Research Fund of Stanford University and from the National Research Council.

Experiment V. The Influence of Three Different Voluntary Sets on the Course of Conditioned Discrimination

Procedure

The physical situation duplicated that of Experiment III, so that, except for instructions, the three groups to be reported were conditioned under circumstances corresponding in respect to the stimuli, order of trials, and time intervals, to those used with Groups A and B of Experiment III. Since all five groups are essentially part of the same series, and intergroup comparisons will be made, the new groups will be designated Groups C, D, and E. All groups were treated alike on the first of the three days of experimentation. On this day the positive stimulus (an illumination change) was presented, reinforced throughout the period by an air-puff to one cornea. Discriminatory conditioning began on the second day and continued for two sessions. In Experiment III, Group A began the discriminatory conditioning without further instructions. The situation was therefore comparable to the usual animal discrimination experiments. Group B, however, received complete information about the positive and negative stimuli, and about reinforcement and non-reinforcement. This information resulted in more rapid discrimination. The new Groups C, D, and E of the present Experiment V all received the information given to Group B, but in addition were given instructions regarding their responses. Group B of Experiment III may therefore be considered a control group, since it differs from Groups C, D, and E, only in that it lacks instructions with respect to responding. The differences between the new groups follow.

Group C.—At the beginning of the second day, before the introduction of the negative stimulus, the subjects of Group C received information about the positive and negative stimuli, and were instructed to wink as rapidly as possible to the positive light which was always followed by the air-puff to the cornea, and to refrain from winking to the negative light, which would not be followed by the puff of air. These instructions therefore supported the tendency towards motor discrimination which would have existed without them.

Group D.—Before the discrimination trials began on the second day, the subjects of Group D were informed about the positive and negative stimuli, and then were instructed to refrain from winking to the positive light which preceded the air-puff, but to wink as rapidly as possible to the negative light, not followed by the puff of air. These subjects were therefore attempting to do exactly the opposite of that which the conditioning tendencies would suggest. To the light which would normally elicit conditioned responses they were attempting to withhold responses; to the negative light, in respect to which conditioned response tendencies would normally be weaker, they attempted to wink promptly.

Group E.—The subjects of Group E, after being informed about the stimuli prior to the second session, were instructed to resist the tendency to react to either the positive or the negative light. The necessity for a group attempting to inhibit all conditioning tendencies will become more evident after the results for the others are presented.

Results for Group C: Voluntary Facilitation of the Discrimination

The subjects of Group C possessed the knowledge of stimulus relationships which had been shown to further the discriminatory reactions of Group B. In addition, they were instructed to react as promptly as possible to the positive stimulus, to refrain from reacting to the negative stimulus. It is possible that the subjects of Group B had adopted a similar set through self-instructions; in that case, there should have been little difference between the responses of Groups B and C. Any considerable difference for Group C means that the instructions have added something to the determination of response not present in Group B.

The gross results are presented in Fig. 1, in which are

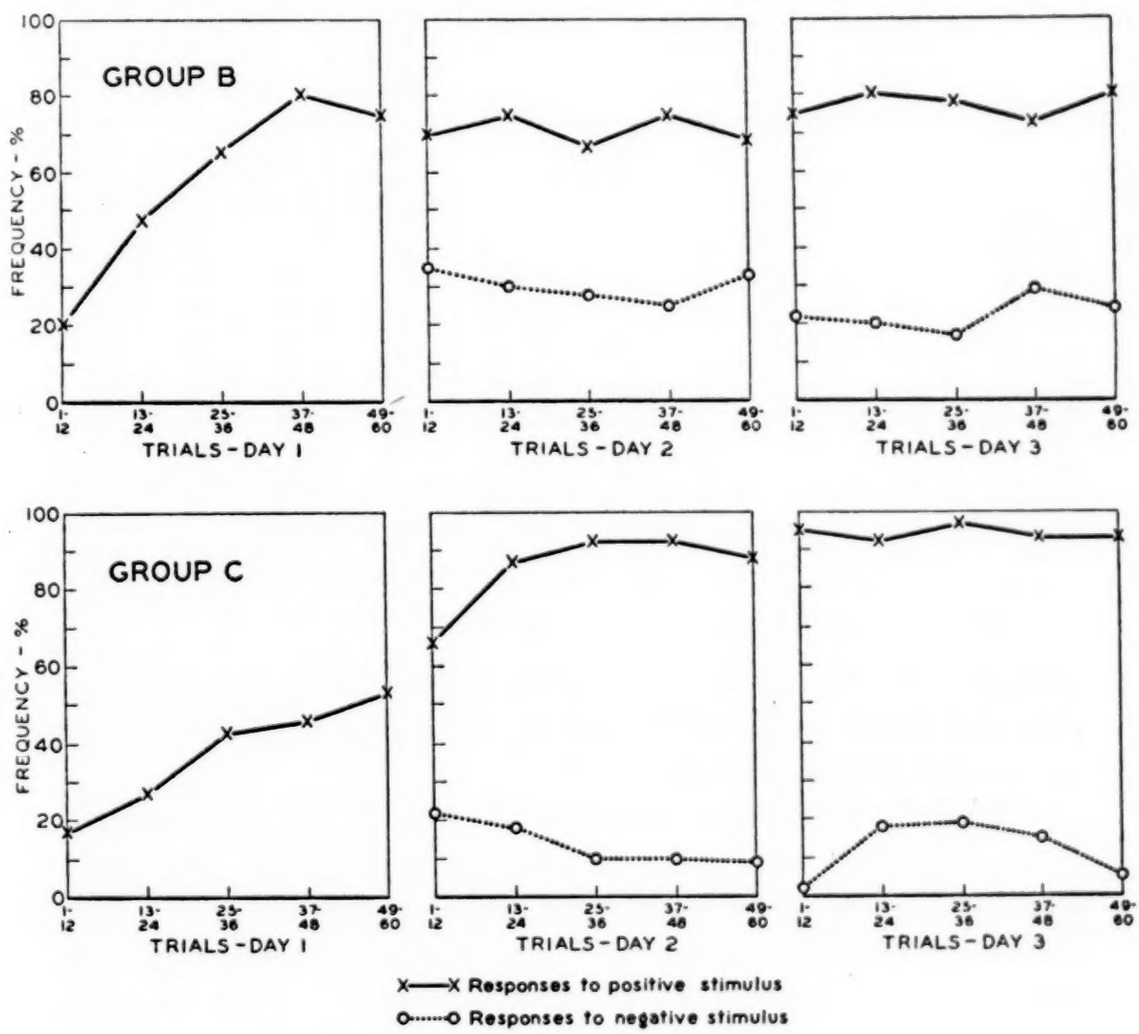

Fig. 1.

plotted the percentage frequency of responses to the positive stimulus throughout the first day of simple conditioning, and the percentage frequency of responses to the positive and negative stimuli throughout the discriminatory sessions for both Groups B and C. Although the subjects of Group C showed somewhat less conditioning than those of Group B on Day 1, when both groups were treated alike, within the discrimination sessions the subjects of Group C show more

TABLE 1

CHARACTERISTICS OF RESPONSES TO POSITIVE STIMULUS WITHIN DISCRIMINATION SESSIONS FOR SUBJECTS OF GROUP B (WITHOUT VOLUNTARY INSTRUCTIONS) AND FOR SUBJECTS OF GROUP C (WITH VOLUNTARY INSTRUCTIONS)

Group B * Without Instructions Regarding Response on Days 2 and 3					Group C With Instructions to Respond as Promptly as Possible on Days 2 and 3				
Subject	Day 1, Simple Conditioning	Days 2 and 3, Responses to Positive Stimulus			Subject	Day 1, Simple Conditioning	Days 2 and 3, Responses to Positive Stimulus		
	Frequency percent	Frequency percent	Amplitude mm	Latency ms		Frequency percent	Frequency percent	Amplitude mm	Latency ms
No. 37....	33	50	15	478	No. 36...	25	90	38	253
No. 39....	68	75	8	435	No. 57...	22	99	40	242
No. 41....	66	92	30	346	No. 58...	82	95	38	282
No. 42....	70	92	38	394	No. 61...	67	83	25	382
No. 43....	40	76	13	433	No. 63...	28	95	40	329
No. 45....	38	35	2	415	No. 66...	32	79	11	480
No. 46....	81	88	40	360	No. 68...	37	100	40	290
No. 48....	67	93	19	376	No. 69...	74	90	39	347
No. 49....	32	52	4	395	No. 72...	5	97	40	184
No. 51....	77	89	17	379	No. 73...	0	73	35	397
Mean....	57.2	74.2	18.6	401.1	Mean....	37.2	90.1	34.6	318.6

* Data for Group B secured in Experiment III (4).

responses to the positive stimulus and fewer to the negative stimulus than those of Group B, thus demonstrating more successful discrimination.

That the differences between the groups are not confined to frequency of response, but are revealed also in amplitude and latency, may be seen from the data of Table 1. The voluntary responses of Group C are both of greater amplitude and of lower latency than those of Group B. Since an arbitrary maximum of 40 mm was used in measuring the amplitude

of responses, it is evident that a large proportion of the responses of Group C were maximal, while those of Group B which reached a maximum were far fewer.

Responses to the negative stimulus were less frequent, and mean values are consequently less reliable. The summary in Table 2 is presented in order to indicate the trends.

TABLE 2

CHARACTERISTICS OF RESPONSES TO NEGATIVE STIMULUS WITHIN DISCRIMINATION SESSIONS FOR SUBJECTS OF GROUP B (WITHOUT VOLUNTARY INSTRUCTIONS) AND FOR SUBJECTS OF GROUP C (WITH VOLUNTARY INSTRUCTIONS)

Group B * Without Instructions Regarding Response (Days 2 and 3)				Group C With Instructions to Refrain from Responding (Days 2 and 3)			
Subject	Frequency percent	Amplitude mm	Latency ms	Subject	Frequency percent	Amplitude mm	Latency ms
No. 37.....	14	3	448	No. 36....	5	27	263
No. 39.....	5	16	447	No. 57....	19	37	188
No. 41.....	70	5	320	No. 58....	16	19	337
No. 42.....	73	32	438	No. 61....	49	12	386
No. 43.....	16	10	426	No. 63....	12	22	394
No. 45.....	23	2	342	No. 66....	5	7	503
No. 46.....	22	39	336	No. 68....	10	32	310
No. 48.....	22	6	388	No. 69....	10	8	377
No. 49.....	4	1	485	No. 72....	0	—	—
No. 51.....	10	6	362	No. 73....	4	40	460
Mean.....	25.9	12.0	399.2	Mean.....	13.0	22.7	357.6

* Data for Group B secured in Experiment III (4).

Both groups show responses of reduced amplitude, with little change in latency. Group C yielded responses of greater mean amplitude and of lower latency than Group B. The difference in this direction, which contradicts the instructions to Group C to refrain from response, is due to the occasional 'false reactions' in which the subject gave a voluntary response to the negative stimulus. These occasional false reactions are familiar in the early stages of discriminatory reaction-time experiments.

The important conclusion to be drawn from the comparison of Groups B and C is that the responses of Group B were not like the 'voluntary' responses of Group C. Although knowledge of the stimuli had hastened the discrimination of Group B over Group A (without knowledge), the

responses of Group B showed characteristics more like those of Group A than like those of Group C. Apparently the control of response through expectancy of stimulus objects is not to be confused with control of response through preparation for specific reactions.

Results for Group D: Voluntary Antagonism to Conditioned Discrimination

While Group C, through instructions to respond voluntarily, bettered the discrimination of Group B, the possibility remains that both groups of subjects were responding under a voluntary set, but the responses of Group B were less prompt and vigorous because the self-instructions were less confident and impelling than the formal instructions given to Group C by the experimenter. By reversing the formal instructions to Group D, calling for voluntary responses to the negative stimulus and inhibition of response to the positive, the nature of the determining tendencies involved in uninstructed conditioned discrimination should be exposed more clearly.

In Fig. 2 are plotted the response frequencies to both positive and negative stimuli throughout the sessions for the subjects of Group D, and of Group E, discussed later. The course of simple conditioning for Group D within Day 1, under instructions uniform with those to all groups, is similar to that found for the other groups, but responses are of smaller average frequency, due presumably to the sampling error which enters into such a small number of subjects. On Days 2 and 3 the voluntary instructions result in a high frequency of response to the negative stimulus, indicating that the subjects are following the instructions. Responses to the positive stimulus, which are supposed to be inhibited voluntarily, continue to increase in frequency until they equal the responses of Group B (Fig. 1), in which no effort to inhibit was called for. Apparently the positive conditioned tendency is strong enough to override the negative instructions.

Characteristics of the responses of individual subjects are given in Table 3, with the mean values from Group B added for comparison. The voluntary responses to the negative

stimulus are quite similar in frequency, amplitude, and latency to the voluntary responses of Group C, as reported in Table 1. Voluntarily inhibited responses to the positive stimulus by Group D differ insignificantly from the responses of Group B to the positive stimulus in spite of the fact that conditioning for Group D was much less satisfactory on Day 1.

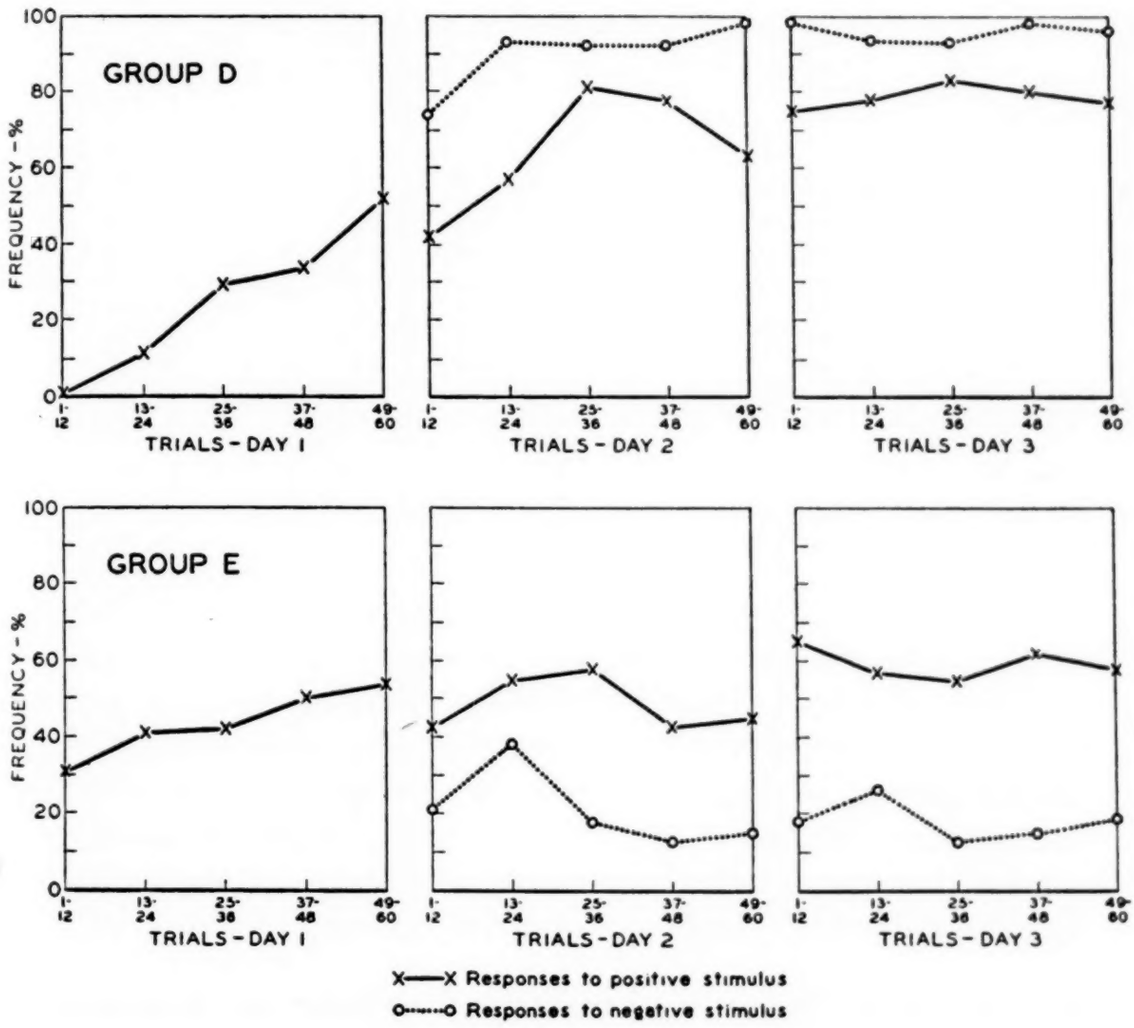

FIG. 2.

It may be conjectured that with better matching of subjects, Group D would have exceeded Group B in responses to the positive stimulus.

The important finding from the results of Group D is that inhibition of response to the positive stimulus was unsuccessful. The similarity of average response characteristics in Group B and Group D does not necessarily mean that the

TABLE 3

CHARACTERISTICS OF RESPONSES TO POSITIVE AND NEGATIVE STIMULI WITHIN DISCRIMINATION SESSIONS FOR SUBJECTS OF GROUP D (WITH ANTAGONISTIC VOLUNTARY INSTRUCTIONS)

Subject	Simple Conditioning (Day 1)	Responses to Positive Stimulus With Instructions to Refrain from Responding (Days 2 and 3)			Responses to Negative Stimulus With Instructions to Respond as Promptly as Possible (Days 2 and 3)		
	Frequency percent	Frequency percent	Amplitude mm	Latency ms	Frequency percent	Amplitude mm	Latency ms
No. 38	15	91	16	438	100	40	319
No. 59	13	22	12	321	89	18	264
No. 60	12	57	26	334	89	40	363
No. 62	45	86	14	395	93	39	424
No. 64	36	82	13	458	95	39	228
No. 65	32	64	20	479	82	37	423
No. 67	39	74	14	410	97	40	218
No. 70	20	70	9	397	95	39	363
No. 71	42	88	27	405	100	40	601
No. 74	12	77	10	404	100	40	259
Mean, Group D	26.6	71.1	16.1	404.1	94.0	37.2	346.2
Mean, Group B*	57.2	74.2	18.6	401.1	25.9	12.0	399.2

* Values for Group B from Tables 1 and 2.

responses of the two groups are similarly composed. Group D probably contains a few false voluntary reactions to the positive stimulus. These responses, of large amplitude and low latency, would tend to offset other responses of reduced amplitude and of lengthened latency as a result of the effort at voluntary restraint. In order to secure some voluntarily inhibited responses to the positive stimulus, uncomplicated by false voluntary reactions, Group E was undertaken.

RESULTS FOR GROUP E: VOLUNTARY EFFORT TO REFRAIN FROM RESPONDING

In neither Group C nor Group D was there much success in overriding conditioning tendencies by voluntary restraint. In both of these groups, however, the restraining tendency was complicated by a set to react voluntarily to the other stimulus. In addition to whatever other influence this divided set may have had, it resulted in some false reactions which under the circumstances could not be discarded from

the population of responses entering into average values. It was therefore desirable to have one group in which all voluntary tendencies were negative, in order to better determine the extent to which voluntary control can negate conditioning. The subjects of Group E were told to refrain from responding either to the positive or to the negative stimulus.

The course of response frequency for Group E has been presented in Fig. 2. The first day corresponds to the first

TABLE 4

CHARACTERISTICS OF RESPONSES TO POSITIVE AND NEGATIVE STIMULI WITHIN DISCRIMINATION SESSIONS FOR SUBJECTS OF GROUP E (WITH INSTRUCTIONS TO REFRAIN FROM RESPONDING)

Subject	Simple Conditioning (Day 1)	Responses to Positive Stimulus With Instructions to Refrain from Responding (Days 2 and 3)			Responses to Negative Stimulus With Instructions to Refrain from Responding (Days 2 and 3)		
	Frequency percent	Frequency percent	Amplitude mm	Latency ms	Frequency percent	Amplitude mm	Latency ms
No. 75	15	15	1	367	14	1	416
No. 76	87	69	8	417	27	3	412
No. 77	12	25	4	289	25	2	287
No. 78	25	40	8	478	10	3	338
No. 79	13	74	3	498	25	1	546
No. 81	76	66	31	518	9	5	485
No. 82	20	82	28	475	7	17	586
No. 83	39	7	1	488	7	3	527
No. 84	74	93	31	447	47	5	392
No. 85	77	82	10	499	23	6	428
Mean, Group E.	43.8	55.3	12.5	447.6	19.4	4.6	441.7
Mean, Group B.	57.2	74.2	18.6	401.1	25.9	12.0	399.2

session for the other groups. The negative instructions begin on Day 2. Discriminatory conditioning proceeds in spite of the negative instructions, although the responses to the positive stimulus are reduced below those of Group D, in which the negative tendency was complicated by the effort to respond voluntarily to the other stimulus.

Response characteristics are summarized in Table 4. The voluntary restraint shows in reduced frequency, reduced amplitude, and lengthened latency. The magnitude of the

difference from Group B is not great, however, especially in view of the less responsiveness of the subjects of Group E on Day 1. The persistence of the discriminatory conditioned response tendencies against completely negative voluntary effort supports the conclusion that conditioned responses are not under direct voluntary control in these experiments.

Extinction Trials

Following the discrimination series of the third day there was a brief series of trials in which neither the positive nor the negative stimulus was reinforced. The resulting percentage frequency of response is shown in Table 5. These

TABLE 5
Percentage Frequency of Response During Extinction

	Responses to Positive Stimulus	Responses to Negative Stimulus
	Frequency percent	Frequency percent
Group B	30	24
Group C	88	7
Group D	40	98
Group E	39	13

data add little to the preceding discussion, except to indicate that the subjects under voluntary instructions continued to respond after the air-puff ceased, while those responding under conditioning influences showed diminution of response during extinction.

Conclusions

(1) *The Participation of Voluntarily Induced Sets in Conditioned Discrimination.*—It is now possible to arrive at some conclusions with regard to the amount of participation of voluntarily induced sets in discriminatory conditioning.

In Table 6 is presented a summary of the characteristics of responses to the positive stimulus by the different groups arranged in order from voluntary restraint through no instructions to voluntary facilitation. Responses are found to fall in the order of increasing frequency, increasing amplitude, and decreasing latency. This is evidence that instruc-

tions exert some control over the process. On the other hand, voluntary restraint does not succeed in overcoming the positive conditioning tendencies, as shown in Groups E and D. The exact quantitative values are not to be interpreted too strictly because of individual variability and lack of equation of groups, but the direction of difference from voluntary restraint to voluntary supplementation is sufficiently demonstrated.[2]

In Table 7 similar values are given for responses to the negative stimulus, with groups again arranged in order from

TABLE 6

SUMMARY OF EFFECT OF INSTRUCTIONS ON CHARACTERISTICS OF RESPONSES TO POSITIVE STIMULUS

Groups in Order of Amount of Voluntary Supplementation of Response	Characteristics of Response on Days 2 and 3		
	Frequency percent	Amplitude mm	Latency ms
Group E Instructed to refrain from responding	55	13	448
Group D Instructed to refrain from responding, but instructed to respond to negative	71	16	404
Group B Without instructions with respect to response	74	19	401
Group C Instructed to respond	90	35	319

voluntary antagonism to voluntary supplementation of response. The same general trends are evidenced: persistence of conditioned responses in spite of voluntary effort to restrain them, along with evidence that responses increase when voluntary restraint is reduced and when voluntary effort

[2] The relative values of Groups B and D are particularly uncertain because Group D was much less responsive than Group B within the simple conditioning of Day 1. The approximate equivalence of values may be a coincidence, for the composition of the responses is not similar. Group D responses include depressed conditioned responses and false voluntary reactions. These have apparently balanced each other in the mean result.

to respond is superimposed on the conditioned response tendencies.[3]

Although voluntarily induced sets participate in conditioned discrimination, they do not suffice to account for the whole process. The tendency to react to both stimuli, but more strongly to the positive one, continues in opposition to voluntary effort to restrain all response.

(2) *Knowledge of Stimulus Relationships vs. Preparation for Specific Acts.*—In an earlier experiment (4) it was shown that

TABLE 7

SUMMARY OF EFFECT OF INSTRUCTIONS ON CHARACTERISTICS OF RESPONSES TO NEGATIVE STIMULUS

Groups in Order of Amount of Voluntary Supplementation of Response	Characteristics of Responses on Days 2 and 3		
	Frequency percent	Amplitude mm	Latency ms
Group E Instructed to refrain from responding	19	5	442
Group C Instructed to refrain from responding, but instructed to respond to positive	13	23	358
Group B Without instructions with respect to response	26	12	399
Group D Instructed to respond	94	37	346

advance knowledge of the stimulus relationships led to more prompt conditioned discrimination. This affects the set to react by way of the expectancy of certain stimulus objects. That this expectancy is not to be confused with a deliberate readiness to respond in predetermined fashion has been shown clearly in the results now presented, which indicate the

[3] The frequency of responses for Group C appears to be too low by comparison with Group E, since Group C responses probably include some false voluntary reactions presumably absent from Group E. This may be due to the same factors which led to lower responsiveness by Group C on Day 1. The large amplitude and low latency of responses in Group C is evidently due to voluntary reactions. A few false voluntary reactions can greatly distort mean values because the population of responses to the negative stimulus is small.

further changes which occur when in addition to expectancy there is a set to react in a particular fashion. While we do not propose to enter here upon a more extended discussion of the factors entering into the different varieties of preparatory adjustment, we believe that the results presented furnish raw material suitable for such a discussion.

(3) *Conditioning and Voluntary Action.*—Because voluntary tendencies have been set against conditioning tendencies in this experiment, it is not necessary to imply that these are two clearly distinguishable orders of response. There is probably a continuum between the varieties of response included as conditioned reactions and those classed as voluntary reactions. While the differences between the two orders of response may be striking under some circumstances (*e.g.*, (**5**) (**10**)), the similarities are also great (**8**) (**9**). Response differences are often specific to the experimental situation, and division into such classes as reflex, conditioned, or voluntary, is of limited usefulness.

Summary

1. Simple conditioned eyelid responses were established during one experimental period by presenting a visual stimulus followed by an air-puff to one cornea.

2. Discriminatory conditioned eyelid responses were developed during a second and third experimental period by presenting another visual stimulus without reinforcement in random order with the previous stimulus, which was always reinforced. A control group from an earlier experiment, in which no voluntary instructions were given (Group B), was used for comparison throughout. Three new groups of 10 subjects each were given different instructions, as follows:

a. Group C was instructed to support the discrimination by responding promptly to the positive stimulus, refraining from response to the negative stimulus.

b. Group D was instructed to respond to the negative stimulus, but to refrain from responding to the positive stimulus. These instructions were antagonistic to the conditioning tendencies.

c. Group E was instructed to refrain from responding to either the positive or negative stimulus.

3. Efforts at voluntary restraint did not suffice to prevent conditioning. Conditioned responses appeared under all circumstances to both positive and negative stimuli. There was an excess favoring the positive stimulus except in the case of Group D, in which voluntary responses were made to the negative stimulus.

4. When the groups are arranged in order from voluntary restraint through voluntary supplementation, responses are found to arrange themselves in approximately that order of increasing frequency, increasing amplitude, and decreasing latency. While the responses are not under full voluntary control, it is evident that they are influenced by voluntarily induced sets.

(Manuscript received November 19, 1937)

References

1. Cason, H., The role of verbal activities in the conditioning of human subjects, *Psychol. Rev.*, 1934, **41**, 563–571.
2. Cook, S. W. and Harris, R. E., The verbal conditioning of the galvanic skin reflex, *J. Exper. Psychol.*, 1937, **21**, 202–210.
3. Freeman, G. L., The galvanic phenomenon and conditioned response, *J. Gen. Psychol.*, 1930, **3**, 529–539.
4. Hilgard, E. R., Campbell, R. K., and Sears, W. N., The effect of knowledge of stimulus relationships on conditioned discrimination, *Amer. J. Psychol.* (To appear).
5. Marquis, D. G. and Porter, J. M , Differential factors in conditioned voluntary and conditioned involuntary responses, *Psychol. Bull.*, 1937, **34**, 772.
6. Miller, J. and Cole, L. E., The influence of a 'voluntary' reaction upon the development and the extinction of the conditioned eyelid reaction, *J. Genet. Psychol.*, 1936, **48**, 405–440.
7. Razran, G. H. S., Conditioned responses: an experimental study and theoretical analysis, *Arch. of Psychol.*, 1935, **28**, No. 191.
8. Rexroad, C. N., Reaction time and conditioning: extinction, recovery, and disinhibition, *J. Exper. Psychol.*, 1937, **20**, 468–476.
9. Stephens, J. M., Data bearing on the conditioning of voluntary reactions, *J. Exper. Psychol.*, 1937, **21**, 236–239.
10. Yacorzynski, G. K. and Guthrie, E. R., A comparative study of involuntary and voluntary conditioned responses, *J. Gen. Psychol.*, 1937, **16**, 235–257.

REINFORCEMENT, EXTINCTION, AND SPONTANEOUS RECOVERY IN A NON-PAVLOVIAN REACTION [1]

BY RICHARD E. P. YOUTZ

Barnard College, Columbia University

In Pavlovian conditioning the indifferent stimulus comes to evoke a reaction that was formerly a component of the unconditioned response. In Thorndike's 'learning by reward' the reaction which becomes associated with a new stimulus may have been quite remote, and hitherto unrelated to the reinforcing (or 'satisfying') state of affairs. As Hilgard (**2**) points out, there has been no general agreement on the relationship between these two types of learning. Thorndike (**18**, p. 192) states that the conditioned reflex is a special case of 'associative shifting,' which he differentiates from 'learning by simple connecting and selecting.' Konorski and Miller (**6**, **9**) and Skinner (**14**, **16**), while differing on terminology,[2] agree that both types may be classified under the head of conditioning.

Hull (**4**) has presented a postulate-system in which the two modes of response-acquisition are derived from a single set of principles, and the conditioned reaction is a special, and limiting, case (p. 17) of learning through the 'law of effect.' If this formulation is a valid one, then the observed regu-

[1] The writer is deeply indebted to Professor Clark L. Hull, in whose laboratory this investigation was performed, for valuable suggestions and criticism during the performance of the experiment and preparation of the manuscript.

This is the first of a series of four studies presented as a dissertation to the faculty of the Graduate School of Yale University in partial fulfillment of the requirements for the degree of Doctor of Philosophy in Psychology, 1937.

The substance of this experiment was reported at the meeting of the American Psychological Association, Hanover, 1936.

[2] Thorndike's 'learning by reward' was called a Type II conditioned reflex by Konorski and Miller (**6**, **9**). Skinner in an early article (**11**) also designates it as a second type, but in a later theoretical article (**14**) calls it Type I. To avoid confusion and because of Thorndike's priority in this field, this type of response-acquisition will be called 'Thorndikian,' as distinguished from the Pavlovian conditioned reaction.

larities, or 'laws,' that have been found with the Pavlovian reaction should also hold in the case of the Thorndikian response. This becomes an increasingly important problem, since, using this hypothesis, Hull (**3, 4**) has been able to deduce many of the phenomena of a more complex type of learning, viz., trial-and-error. Spence (**17**) has also used the principles of reinforcement and extinction in an analysis of discrimination learning, which he distinguishes from 'trial-and-error,' or 'problem-box,' learning.

Skinner (**11, 12, 13**) has shown that the form of the acquisition and extinction curves of a Thorndikian response (Skinner's Type I) is similar to that found in conditioning.[3] The experiment here reported deals with the quantitative relationships between reinforcement, extinction, and spontaneous recovery after two amounts of training of a similar Thorndikian response.

Apparatus and Procedure

The subjects, 18 male rats of the Experimental Colony strain from the Wistar Institute, were 103 days old at the beginning of the experiment and had not received any previous training. The rats were allowed to eat for one hour each day upon a diet of calf-meal supplemented with cod-liver oil. Daily training occurred at least one half-hour before feeding, so that in each case, during the training or experimental extinction the rat had been without food for approximately 23 hours.

The apparatus consisted of two similar experimental boxes and the stylographic recording system. In order that there should be as few as possible external stimuli which might inhibit or disinhibit the animals during reinforcement and extinction, these boxes were constructed of inch-thick concrete, lined with celotex and made fairly air-tight with rubber gaskets at all joints and doors. Vibrational stimuli from the floor were reduced by resting the boxes on felt-covered leather straps slung on frames, which in turn were insulated from the supporting tables by sponge-rubber. A low intensity hum (120 dv) was produced in each box by a phone-unit connected to the secondary of an inductorium (vibrator inoperative). The inductorium, which was supplied with A.C. from a transformer, was used in order to provide a sound-intensity lower than was possible with the transformers available. The air was kept at room temperature by a ventilating system which also made a high-frequency hiss. These sounds served to mask any small adventitious stimuli not already excluded by the walls and at the same time simulated the usual distant hum of noise common in the rats' living quarters. The interior of the box was lighted from above through a double-paned observation-window.

The animal compartment was 17″ long, 16″ wide, and 11″ high, giving the rat comparative freedom of movement. At one end of this compartment was a panel. In front of the panel, parallel to it, and 3/4″ from it was suspended a small horizontal

[3] However, he reports "failure to obtain 'disinhibition'" (**15**).

bar 3″ long (see Fig. 1). This bar was 3½″ from the floor of the box and could be depressed 1/2″ by a rat exerting a pressure of 15 grams. Depression of the bar made an electrical connection which released a pellet of food into the food-tray beneath the bar and activated an electromagnetic marker on the stylograph.[4]

The mechanical arrangement of the horizontal bar was such that when it had moved down 1/4″, the electrical contact was made and continued closed until the bar returned to within 1/16″ of its 'at-rest' position. This was done to prevent the rat from obtaining several pellets by moving the bar up and down within a small range, which occasionally happened during preliminary experiments before this device was installed.

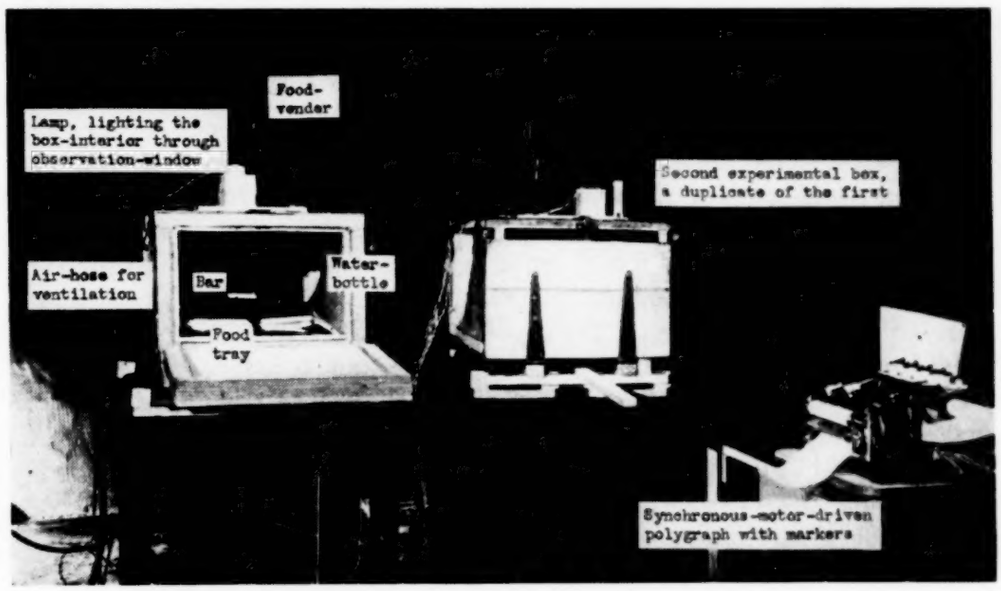

FIG. 1. Experimental boxes and recording system. The horizontal bar may be seen in position in the left box. When this bar is depressed by the rat, the vender releases a food-pellet, which drops through a hole in the top of the box and is transmitted to the food-tray through a tube just behind the panel. Each depression of the bar, whether or not followed by the release of a pellet, is recorded on the polygraph at the right. When the box is closed, ventilation is effected through an air-hose attached to a vacuum-connection. The hole in the top of the box for the pellet-tube also serves as an air-intake. The animal-chamber is lighted by a covered lamp which shines down through the observation-window.

The pellets of food which constituted reinforcement, or reward, were made of the same material as the rats' daily food. These pellets were large enough to keep the rats working and yet weighed only 1/25 of a gram so that 10 of them did not effectively decrease the performance based on the hunger drive. The procedure may be conveniently classified under four headings: 1. Habituation to apparatus, 2. Preliminary training, 3. Reinforcement, and 4. Extinctions.

1. *Habituation to the apparatus* was effected on the four days preceding training. Each rat became familiar with the experimental situation by being placed in the box

[4] Although these boxes and the recording system were not the same as those used by B. F. Skinner, the writer is indebted to him for the idea of using such a bar in a sound-shielded box (11).

one hour the first day and 1/2 hour on each of the three succeeding days. The horizontal bar was not present and the rat was allowed to explore the box thoroughly. On each day five pellets were placed in the food-tray so that the rat could become accustomed to eating food in the box. After habituation the rats were divided into two groups of nine each, Group A to receive forty reinforcements before extinction, Group B to receive ten reinforcements before extinction.

2. *Preliminary training* occurred on the morning following habituation. Each Group A rat was placed in the experimental box with no bar present. Then with a cord attached to the appropriate lever inside the box the experimenter made a contact which released a pellet of food into the food-tray. The making of this connection also produced a click inside the box where the rat could hear it. Each rat learned to go to the food-tray and get a pellet when the click sounded and was given 30 pellets in this way.

3. *Reinforcement* for the Group A rats began on the next morning. The animal was placed in the experimental box with the horizontal bar in position. A faint smudge of dampened mash was placed above the bar. The rat investigated this and in the process depressed the bar. This produced the click to which he had been trained, and also released a pellet of food which fell into the food-tray. Upon hearing the click the rat procured the pellet of food. Since he had just previously depressed the bar, this constituted one reinforcement. He then continued to depress the bar and eat pellets until he had finished ten. The experimenter at once took him from the experimental box. The rat was returned to his home-cage, and a half-hour later given his regular daily feeding. A similar procedure was followed on the second, third, and fourth days, with the exception that no smudge of mash was placed over the bar. Thus, at the end of the fourth day the rats in Group A had received a total of forty reinforcements.

The same general procedure was followed for the Group B rats, which received only ten reinforcements. After the four-day habituation period each Group B rat was for three consecutive mornings placed in the experimental box with no bar present. He ate the ten pellets found in the food-tray each day, but these did not constitute reinforcements because the bar was not present and the animal did nothing but pick the food out of the tray. This served to keep the conditions for the ten-reinforcement group the same as for the forty-reinforcement group except for the experimental variable, the presence and depression of the bar before each pellet. On the fourth day the animal was trained to get a pellet at the click of the mechanism and on the fifth was allowed to depress the bar ten times and procure ten pellets. After the tenth pellet the food was turned off and extinction began.

4. *Extinction.*—Immediately after the last reinforcement, the experimenter threw a switch so that food no longer fell into the food-tray following the rat's depression of the bar. Extinction was considered to be complete when a period of twenty minutes had elapsed during which there was no response to the bar. The rat was then removed from the box and returned to his home-cage.

At the beginning of experimental extinction each rat in the two groups had just received ten pellets, the only food it had taken in the preceding 23 hours, but Group A had been reinforced forty times and Group B only ten times. After extinction the rats were returned to their home-cages and given their regular daily ration. On the next day the strength of the response-tendency was again determined by another extinction to the same criterion. Then with a view to determining the relative stability of the differentially reinforced responses the rats were given one more extinction after 55 days.

Reinforcement

Described in the conditioning terms of frequency and latency, the Thorndikian response increased in frequency and decreased in latency during training, although in this situation these two variables are not easily differentiated. Since in this type of learning the 'conditioned stimulus' is continuous and the organism is free to respond quickly, slowly, or not at all, it is clear that after one response a decrease in the latency of the next response will also increase the frequency. This change in the speed of responding is plotted in Fig. 2, which

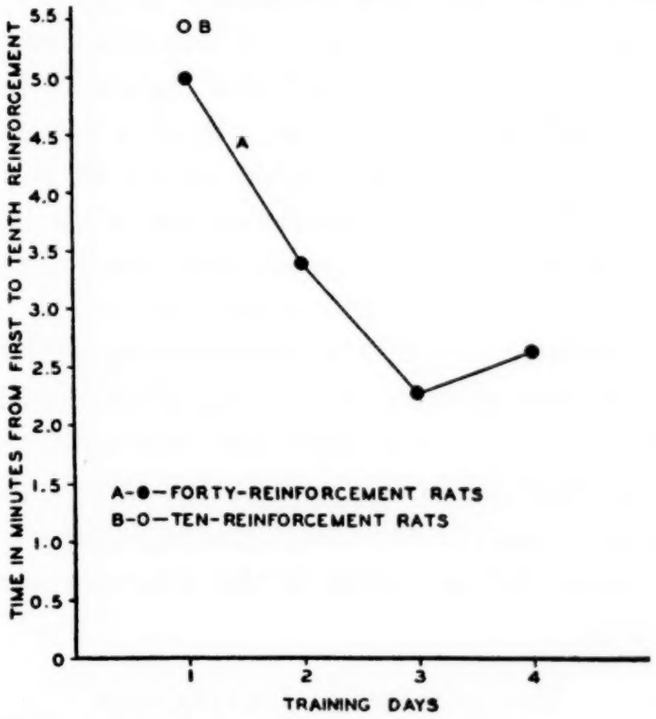

Fig. 2. Time required for ten reinforced responses on successive days of training. The solid dots indicate the time for ten reinforcements on each of the successive training-days for Group A. The open circle shows the mean time for ten rewarded trials on the single day of training for Group B. Each point in the above figure represents the mean for nine rats.

shows the mean time from the first to the tenth response on each of the four reinforcement-days for Group A, and on the one reinforcement-day for Group B. The comparability of the early training is shown by the small difference between the times for the first day for the two groups. The negative acceleration and reversal of the curve for Group A implies that, if there is a positive correlation between speed of

reinforcement and resistance to extinction, then the acquisition of this response-tendency for Group A had gone almost as far at thirty reinforcements as it had at forty, and that further reinforcements would add decreasing amounts to the strength of the tendency.

Further examination reveals the above-mentioned positive correlation between the rate of response during acquisition and resistance to extinction. This is expressed as a *rho* of $-.77 \pm .14$ between time in minutes to get forty reinforcements and number of responses during immediate extinction. That is, the shorter the time necessary to get forty reinforcements, the greater the number of non-reinforced responses necessary for extinction. Since this figure is for Group A alone, it is based on only 9 cases. Such a correlation might well be the result of a fairly wide range of activity levels. However, this figure compares favorably with that obtained by Mateer (**7**) who worked with the conditioned salivary response in children. She found an r of $-.45$ between the number of trials necessary for conditioning and the number of responses during extinction. Using Mateer's data, Hunter (**5**) found this to be $-.80$ when age was held constant. It is to be noted that Mateer's correlation is calculated on the *number of trials* required for conditioning while in this experiment the corresponding value is the *time required* for forty reinforcements.

Experimental Extinction

In determining the effect of two amounts of reinforcement on the subsequent extinctions the following measures were used: number of responses, total time, and responses per minute during extinction. The change in response-rate during the course of extinction was also plotted. In the figures the values are in each case the means for an experimental group of nine rats.

During the extinctive process the curve of change in the rate of responding is negatively accelerated, as it was during acquisition, but the change is in the opposite direction. Figs. 3 and 4 show the mean number of responses for successive

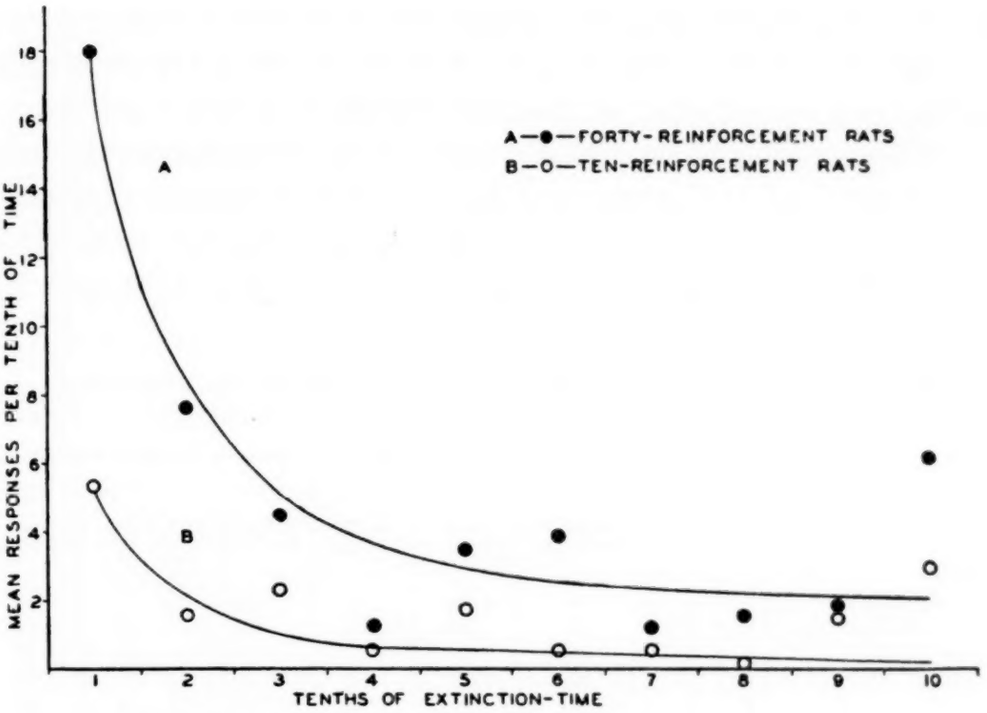

FIG. 3. Modification in response-frequency during an extinction following immediately after the last reinforcement. Each point in the above figure represents the mean for nine rats. Extinction-time was measured from the point at which the rat was placed in the experimental box until the beginning of an interval of twenty minutes during which there was no response to the bar. This interval necessarily began for each rat just after it had depressed the bar one or more times. Thus, for all the animals the last tenth of the extinction-time contained one or more responses. Since this was not true for all of the other fractions of the extinction period, there is an apparent, though probably not a true, rise at the end of both curves. This has been eliminated in the smoothed curves shown above.

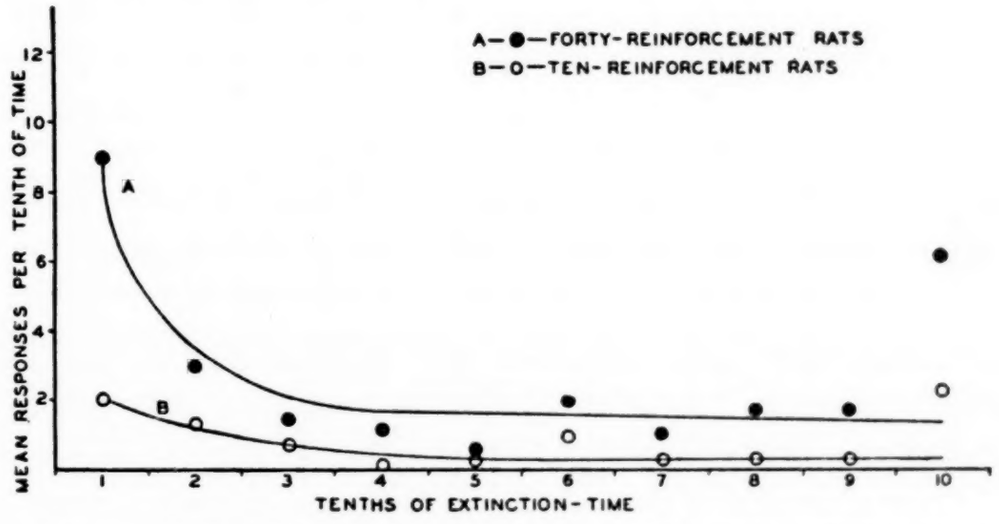

FIG. 4. Modification in response-frequency during a second extinction twenty-four hours after the first. No training was given between the first and second extinction, so that the values shown above are the result of spontaneous recovery. The N was 9 for each of the points plotted above. (*Cf.* Fig. 3.)

tenths of extinction-time during the first two extinctions of Groups A and B. The rate for Group A, the forty-reinforcement rats, is higher in both cases during the entire period.[5]

During each of the three successive extinctions the rats that have had the larger number of reinforcements require a greater number of non-reinforced responses for extinction (Table I). With only two exceptions this was also true for

TABLE I

RESISTANCE TO EXTINCTION AFTER TWO AMOUNTS OF REINFORCEMENT

Group	Rat No.	Extinction-responses			Time for Extinction (Minutes)		
		Immediate Extinction	After 24 hrs.	After 55 Days	Immediate Extinction	After 24 hrs.	After 55 Days
Group A. Forty reinforcements	1	21	14	7	37	10	19
	2	56	26	19	39	23	12
	3	49	15	24	38	10	39
	4	74	46	12	43	46	14
	5	87	40	52	46	35	81
	6	50	10	47	39	8	19
	7	18	36	6	3	32	3
	8	7	28	24	7	25	27
	9	67	35	1	36	24	1
	Sum	429	250	192	288	213	215
	Mean	48	28	22	32	24	24
Group B. Ten reinforcements	10	21	23	35	13	36	80
	11	18	15	12	10	14	20
	12	37	14	18	29	11	20
	13	5	0	0	9	0	0
	14	22	7	12	46	19	30
	15	10	4	14	26	5	18
	16	11	4	19	11	1	41
	17	4	3	3	1	1	12
	18	21	7	17	7	4	4
	Sum	149	77	130	152	91	225
	Mean	17	9	14	17	10	25
$\frac{\text{Dif.}}{\sigma_{\text{dif.}}}$ for Groups A and B		3.19	3.96	1.24	2.18	2.34	0.10

extinction-time and responses per minute during the extinctive process. It is interesting to note that although the weaker excitatory tendency received only 25 percent as many

[5] From observations of the rats' behavior during this experiment a change in amplitude during the extinction of the Thorndikian response seems probable. So far as the writer can discover, no systematic investigations of this phenomenon have been published.

reinforcements as the stronger, yet its later strength in number of non-reinforced responses was never less than 32 percent as great. During immediate extinction the weaker tendency yielded 1.7 as many extinction-responses as it had received reinforcements, while the stronger gave only 1.2 as many. It seems plausible to assume that, like other curves of acquisition, the curve expressing the increase in strength of the tendency in relation to the number of reinforcements is negatively accelerated. This relationship is shown in Fig. 5.

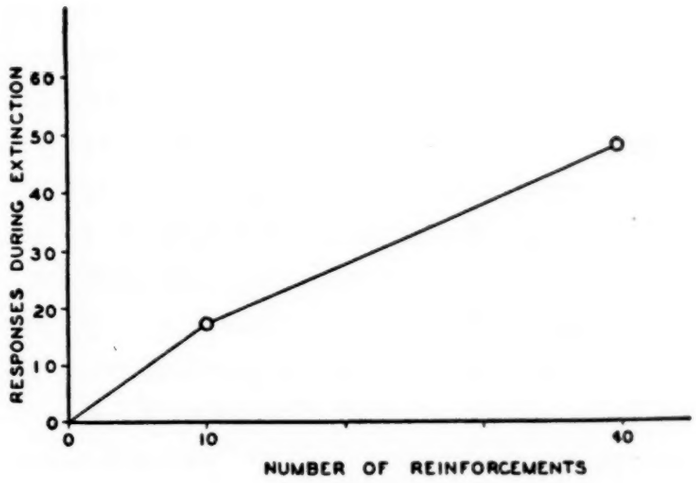

FIG. 5. Resistance to extinction after ten and forty reinforcements. In each case N is 9.

While most experimenters on conditioning have used amplitude of response as the criterion to which the conditioning process was carried, some have also reported the frequency of appearance of the response during the acquisition period in relation to the number of unreinforced responses during extinction. Bernstein (1), working on conditioned eyelid reactions, reports a *rho* of .88 between the 'percentage of conditioning' during fifty paired stimulations and the number of non-reinforced conditioned responses during an extinction series. Table I and Fig. 2 show a similar relationship between number of reinforcements during training and number of responses during extinction for the Thorndikian response. In this connection Pavlov remarks:

> It is clear that the more vigorous a conditioned reflex, or in other words the greater the intensity of the excitatory process, the more intense must be the inhibitory

process in order to overcome it, and therefore the greater the number of unreinforced repetitions necessary to bring about complete extinction (10, p. 61).[6]

In many experiments on learning where a choice is demanded of the organism, the assumption has been made that the 'dominance-order' of the responses determines which one will be made first. But in most cases, the only way to find the 'dominant' response is to place the organism in the experimental situation and record its first choice. This, of course, is completely circular. It is suggested that in this experiment is illustrated a method by which the 'dominance' of a response may be controlled. Two stimulus-response relationships of about equal difficulty can be trained separately, one with a large number of reinforcements, and one with only a few. When these two responses are now brought into a common environment, a situation is set up in which the organism possess two response-tendencies of unequal, but known strengths. These conditions should be especially useful in the study of habit-competition. McCulloch and Pratt (8) have recognized the importance of preliminary training and have given a brief discussion of it in connection with their experimental work on the 'pre-solution period' in discrimination-learning.

Change in Strength with Successive Extinctions

Thorndikian and Pavlovian responses may also be compared on the change in strength brought about by successive extinctions. In summarizing his remarks on internal inhibition, Pavlov says:

> As a result of repetitions of experimental extinction on the same animal the zero level of a fresh extinction is reached more rapidly (10, p. 61).

Figure 6 shows this to be true for both degrees of training of the Thorndikian response, particularly at the second extinction. The resistance to extinction shown by the response at 55 days is most probably a product of (1) permanent decrement in response-strength brought about by previous

[6] When the terms 'inhibition' and 'extinction' are used by the present writer, behavioral decrement is indicated, rather than an underlying neurophysiological mechanism of the Pavlovian type.

extinctions; (2) the amount of spontaneous recovery; and (3) the retention of this recovery until the next extinction. From the data available it is not possible to determine the rôle of each of these factors, although the writer has reported elsewhere (**19**) that in a test of retention, the resistance to extinction of this type of response is greater 15 days after training than at one day afterward.

Whether this is also true for a 55-day interval has not yet been determined, but if a tendency in that direction is

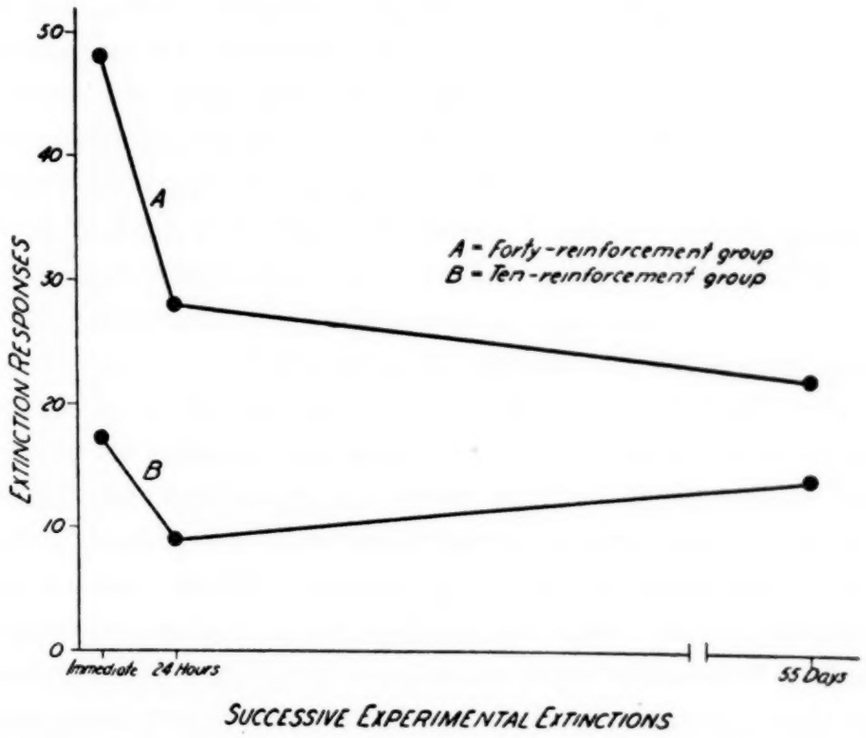

FIG. 6. Number of responses during successive extinctions. The last rewarded trial was made before the beginning of the first extinction. The points on each curve represent the means for nine rats.

assumed, then both spontaneous recovery and the *rise* in the retention curve would tend to increase the resistance to extinction. This may account for the levelling off of the curve for Group A in Fig. 6, between the 24-hour and 55-day extinctions. The reversal in the curve for Group B may indicate that spontaneous recovery is proportionally greater for weaker response-tendencies, but more probably it is the result of variability that would disappear with a larger number of subjects.

Spontaneous Recovery

That the Thorndikian response recovers spontaneously, contrary to the law of disuse, is shown by the fact that after extinction to a point where no responses were made for twenty minutes, a second extinction 24 hours later contained a measurable number of responses in 17 out of 18 animals. While the resistance to extinction at 55 days is, as stated above, partly a function of the *rise* in the retention curve of this type of response, this effect is not markedly present 24 hours after training. In addition, another extinction curve is regularly obtained as little as 20 minutes after the completion of the first extinction (**19**). Spontaneous recovery may then be justifiably listed as one of the characteristics of this response, especially after an interval as short as 24 hours.

Figure 6 and Table I show this recovery and, moreover, indicate that the ratio of second-extinction responses to first-extinction responses is approximately the same for both groups, being .58 for Group A and .53 for Group B. This may also be taken to show that the *speed* of spontaneous recovery is determined by the original number of reinforcements, since both groups were extinguished to the same criterion at immediate extinction, but recovered different absolute amounts during 24 hours. While the stronger response-tendency was recovering to a point at which 28 extinction reactions were necessary to reduce it to criterion, the weaker one recovered to a point where only 9 were needed. The weaker tendency, then, recovered 32 percent as fast as the stronger one. The relation at the first extinction was substantially the same, the weaker being 35 percent of the stronger. This ratio changed markedly at the 55-day extinction, where it became 64 percent, suggesting that either the curves of spontaneous recovery of the 40-reinforcement and 10-reinforcement response-tendencies were quite different, or, as previously suggested, that some additional factor had become active.

Concerning spontaneous recovery in the conditioned response Pavlov ventured to say:

> Left to themselves extinguished conditioned reflexes spontaneously recover their full strength after a longer or shorter interval of time, but this of course does not apply

to conditioned reflexes which are just in process of formation. . . . All those conditioned reflexes which have been fully established, invariably and spontaneously return sooner or later to their full strength.[7]

Summary and Conclusions

1. A Thorndikian response was examined experimentally to determine whether it exhibited characteristics similar to those found in the Pavlovian conditioned response, as postulated by several writers on the subject. Nine rats learned a bar-depressing response, receiving forty reinforcements, followed by three successive extinctions, (1) immediately following training, (2) twenty-four hours after the first, and (3) fifty-five days after the second extinction. Another group of nine rats followed the same experimental schedule after receiving only ten reinforcements.

2. The Thorndikian response showed a decrease in latency and an increase in frequency during acquisition similar to that found in conditioning.

3. There was a rank-order correlation of $-.77 \pm .14$ between learning-time and trials necessary for extinction for the forty-reinforcement rats, a correlation of the order and sign also found in certain conditioning experiments.

4. Of the three measures used on the successive extinctions, the number of non-reinforced responses made before an arbitrary zero was reached proved the most reliable in differentiating between the rats receiving forty and those receiving ten reinforcements.

5. The ratio of responses during the first extinction to reinforced responses during training was 1.2 for the forty-reinforcement rats and 1.7 for those receiving only ten reinforcements. This suggests that the curve expressing the increase in strength of the response-tendency in relation to the number of reinforcements is negatively accelerated.

6. Successive extinctions required decreasing numbers of non-reinforced responses to reduce the strength of the tendency to an arbitrary zero.

7. Contrary to the 'law of disuse,' spontaneous recovery was found to occur in the Thorndikian response during

[7] The problem raised by this statement is how to determine the point at which a conditioned reflex has become 'fully established.'

intervals of twenty-four hours and fifty-five days, although it was likely that another factor was also active during the fifty-five day interval. During the twenty-four hour interval both groups showed approximately the same percentage of recovery (53 percent and 58 percent) as measured by number of extinction responses.

8. In terms of the variables considered, the Thorndikian response was found to exhibit a functional similarity to the conditioned response.

(Manuscript received November 8, 1937)

REFERENCES

1. BERNSTEIN, A. L., Temporal factors in the formation of conditioned eyelid reactions in human subjects, *J. Gen. Psychol.*, 1934, **10**, 173–197.
2. HILGARD, E. R., The relationship between the conditioned response and conventional learning experiments, *Psychol. Bull.*, 1937, **34**, 61–102.
3. HULL, C. L., Simple trial and error learning: a study in psychological theory, *Psychol. Rev.*, 1930, **37**, 241–256.
4. ——, Mind, mechanism, and adaptive behavior, *Psychol. Rev.*, 1937, **44**, 1–32.
5. HUNTER, W. S., Conditioning and extinction in the white rat, *Brit. J. Psychol.*, 1935, **26**, 135–148.
6. KONORSKI, J. A., AND MILLER, S. M., On two types of conditioned reflex, *J. Gen. Psychol.*, 1937, **16**, 264–272.
7. MATEER, F., *Child behavior.* Boston: Badger, 1918. Pp. 239.
8. MCCULLOCH, T. L., AND PRATT, J. G., A study of the pre-solution period in weight discrimination by white rats, *J. Comp. Psychol.*, 1934, **18**, 271–290.
9. MILLER, S., AND KONORSKI, J., Sur une forme particulière des réflexes conditionnels, *C. r. de biol.*, 1928, **99**, 1155–1157.
10. PAVLOV, I. P., *Conditioned reflexes:* an investigation of the physiological activity of the cerebral cortex. (Trans. and ed. by G. V. Anrep.) London: Oxford Univ. Press, 1927. Pp. xv + 430.
11. SKINNER, B. F., On the rate of formation of a conditioned reflex, *J. Gen. Psychol.*, 1932, **7**, 274–286.
12. ——, On the rate of extinction of a conditioned reflex, *J. Gen. Psychol.*, 1933, **8**, 114–129.
13. ——, 'Resistance to extinction' in the process of conditioning, *J. Gen. Psychol.*, 1933, **9**, 420–429.
14. ——, Two types of conditioned reflex and a pseudotype, *J. Gen. Psychol.*, 1935, **12**, 66–77.
15. ——, A failure to obtain 'disinhibition,' *J. Gen. Psychol.*, 1936, **14**, 127–135.
16. ——, Two types of conditioned reflex: a reply to Konorski and Miller, *J. Gen. Psychol.*, 1937, **16**, 272–279.
17. SPENCE, K. W., The nature of discrimination learning in animals, *Psychol. Rev.*, 1936, **43**, 427–449.
18. THORNDIKE, E. L., *The psychology of wants, interests, and attitudes.* New York: Appleton-Century. 1935. Pp. x + 301.
19. YOUTZ, R. E. P., The change with time of a Thorndikian response in the rat. (In preparation.)

A STUDY OF BACKWARD AND REMOTE FORWARD ASSOCIATION [1]

BY MARGERY HAYDEN TROWBRIDGE

University of Wisconsin

I. Introduction and Historical Summary

The problem of remote association is whether associations or connections are formed only between consecutive items of a series, as the series is learned in the forward direction, or whether they are also formed between remote terms in the forward direction or between items in the backward order. More fundamentally, the basic problem is the importance of temporal sequence of stimuli in learning, and studies of remote association in human serial learning are therefore related to studies of backward conditioning, anticipatory responses in learning, and backward association in animal maze learning.

In the present study of remote association in serial learning, we have studied the typing of a series of consonants, measuring the amount of learning by improvement in speed and accuracy. We have hoped by using this procedure to eliminate some of the objections to the techniques of previous investigators.

Ebbinghaus (4), the first experimenter on this problem, reported his studies of remote association in his monograph on memory. He learned series of 16 syllables, which he had spread out before him, to the point of one correct repetition; 24 hours later he learned derived lists made up in several ways from his original lists. The amount of association was measured by savings in relearning. The saving in relearning original lists was 33.3 percent, in lists derived by skipping one syllable, 10.8 percent, in lists skipping seven syllables, 3.3 percent. The saving in relearning reversed lists was 12.4 percent.

[1] The writer wishes to express her indebtedness to Professor Hulsey Cason for suggestions and help given in the course of the present investigation. Thanks are also due to Miss Rosella Lieder for assistance in carrying out the experimental work.

Münsterberg (**14**) criticized Ebbinghaus' method by saying that since he had the series of syllables spread out before him Ebbinghaus had simultaneous associations and not true serial reverse or skipping associations. Müller and Schumann (**13**) and Müller and Pilzecker (**12**) were influenced by this criticism and carried out experiments using a kymograph. They found that although the subject could see only one syllable at a time, some subjects retained the visual image of the first syllable when the next syllable was shown. Their subjects repeated syllables in regular measures, trochaic and anapaestic, and it was found that there was a tendency to a redintegration of the whole measure.

The work of Wohlgemuth (**15**, **16**) grew out of that of Müller. Short series of diagrams and of nonsense syllables were presented by a Müller memory apparatus until the subject thought he knew the list. Then a single syllable or diagram was exposed, and the subject picked, from a list of syllables and diagrams arranged in haphazard fashion, the one which he had thought of in response. More responses in the backward direction were found with diagrams than with syllables. With syllables, about twice as many forward as backward associations were found. In another experiment in which pairs of colors and diagrams and nonsense syllables were used, the same results were found. Wohlgemuth's nine observers all obviously had insight into the problem.

Cason (**1**) reopened the question of remote association with a criticism of Ebbinghaus' methods. He suggested that Ebbinghaus' results were due to fluctuations in attention in which he glanced backward or forward over the series, and to practice in thinking the whole list through during the first imperfect recitations. Cason also reinterpreted the problem in the light of contemporary stimulus-response theories of association.

In the two experiments on the problem carried out by Cason (**2**, **3**), some evidence was found for backward association in learning series of nonsense syllables and familiar words. This evidence the experimenter attributed to irregularities in learning, eye-movements, etc., which meant practice

in the backward direction. In a study of the learning of logical material, it was found that when learning of a prose passage is weak, more backward associations are formed than when it is well learned. When the passage is well learned, backward associations are, in general, inhibited. No remote association was found in prose passages that had been well learned.

Garrett and Hartmann (**5**), who were influenced by Cason, assumed that the crux of the problem was the method of presenting materials. They had their 10 subjects learn lists of 12 syllables which they read to themselves, and lists which were presented on a rotary tachistoscope. Results for the tachistoscopic method and for the reading method were about the same and favored backward association. But the authors pointed out that in all cases of simple reversal, the subjects had seen through the problem. One subject reported that he had 'shifted the gears of his mental set' when confronted by the reversed list. The authors therefore concluded that it seemed improbable that what they called true backward associations had occurred.

Hall (**8**) also responded to Cason's experiments, suggesting that overlearning was a complicating factor and that the time of retesting might be important. She studied remote forward association in the learning of nonsense syllables shown in a Hull automatic exposure apparatus. Each of the 40 subjects relearned half of the control and half of the test material immediately and the remaining material after one week. In immediate relearning, test lists showed 4.9 percent more saving than control; in relearning after a week, test lists showed 33.4 percent more saving than control lists.

Lepley (**10, 11**) has presented a theory that remote forward associations are of the nature of delayed conditioned reactions. In his experimental investigations he tested inferences drawn from this theory, particularly concerning the importance of the interval of forgetting and the degree of learning. The method of learning used by Lepley, that of anticipation, was undoubtedly responsible for some of the results. In the first trial, subjects read each syllable of a series aloud as it appeared

in the aperture of a tachistoscope. On each succeeding trial they were to attempt to anticipate and say aloud the succeeding syllable before its appearance. This was continued to the point of one perfect anticipatory performance. In the testing part of the program, subjects learned derived lists, constructed by skipping one syllable, in the same way. The interval of forgetting was varied and each subject was tested at six different intervals. In the second experiment, the interval of forgetting was held constant while the degree of original learning varied from one to six perfect performances.

A striking feature of Lepley's results was the lack of saving in relearning both test and control material. Remote association appeared in these data only as a smaller amount of interference in relearning remote forward than in relearning control lists. A reliable difference favoring test over control lists appears in the first experiment only at the 30-minute interval; at the 10-minute, three-hour, six-hour, and 24-hour periods results favor the control lists, that is, there is no remote forward association. Results of the second experiment supported the theory that overlearning results in a lesser mensurability of remote association.

Guthrie (**6**, **7** esp. pp. 52–53) reports an experiment done with Albaugh. Nonsense syllables and nonsense figures were arranged in sets of 10 pairs. These were photographed on a picture film and run through seven times before the subjects. Then the figures, or syllables, were run through slowly and subjects were asked to write the syllable or figure corresponding with the one shown. There was no significant difference between the forward and backward associations. Hermans (**9**) used the same technique with pairs of syllables presented photographically. He concluded that his results were evidence for backward association, although he pointed out a number of disturbing factors in the learning and said in summary that the significance of the results obtained was not at all clear.

It has been observed in all the experiments on remote association that the way in which the material is presented and the subject's review of the material, his thinking forward

and backward, have affected the results. In experiments like those of Ebbinghaus where syllables are spread before the subject, it has been suggested that the subject glances before and after in the series and obtains direct practice in both directions. Cason's subjects also did this. Investigators who have attempted modes of presenting material which make direct practice impossible have found themselves involved in the question of memory review. Müller and Schumann, Wohlgemuth, and Guthrie all reported that subjects would keep one item in mind until another was presented, or would recall a previously presented item in such a way that there was really simultaneous rather than successive perception. This is particularly true in paired associate experiments, which seem, for this reason, to be unsatisfactory investigations of the problem. Also, Müller and Schumann, Garrett and Hartmann, and others have pointed out that in some cases subjects *recognized* material as backward. This fact, of course, complicates the problem. Moreover, the anticipatory method used by Lepley is complicating to the problem of association, involving as it does an ideational review of all stimuli to which the subject has been responding. In short, when ideational rehearsal takes place, experimenters cannot get unequivocal results regarding the significance of temporal sequence of stimuli in learning.

In the present experiment, the subjects typed the material given them as fast as they could. They did not have to look backward or skip forward. Moreover, the material and the testing method were such that the subjects were not tempted to mental rehearsal. In this respect the experiment was better controlled than any previous study.

The significance of time of retest, which has been considered important by some investigators, notably Hall, was checked. Also, by employing two experimental procedures, the same in all particulars except length of practice, the influence of the degree of learning was studied.

II. Experiment A

The two experimental procedures will be called Experiment A and Experiment B. The author acted as experimenter in Experiment A, and Miss Rosella Lieder, working

with and under the direction of the author, was the experimenter in Experiment B. Experiment A will be described first.

Materials.—The materials in the experiment were series of 20 consonants. The test material consisted of three lines which were made as equal in difficulty as possible. The practice material, or practice block, was made up of five 20-consonant lines, including one test line reversed, a second test line forward but skipping one letter, and the third test line separated so that its letters appeared in the vertical columns of the block. Two sets of this sort were used. The first set follows:

Test lines:

V D N T F M Q K Z R X C P B G W L H S J (control)
S G K R C J V M D F Q W H Z B X N L T P (backward)
F C N X D K S P G Q V B J W T Z L M R H (remote forward)

Practice block:

(1) P T L N X B Z H W Q F D M V J C R K G S
(2) *F* X *C* B *N* W *X* Y *D* C *K* Q *S* D *P* X *G* V *Q* Z
V S *B* W *J* L *W* R *T* J Z S *L* K *M* P *R* M *H* Q
(3) W D H T G M B K N R T C Y B T W N H M J
L V K N R F V Q G Z D X F P X G J L F S

(1) Reverse or backward combination. This is the SGK . . . LTP test line simply reversed.

(2) Remote forward combination. This is the FCN . . . MRH line with the letters separated by an interpolated letter.

(3) Control combination. This is the VDN . . . HSJ line, in the following order: from the second letter of the fifth line, to the second letter of the fourth line, to the fourth letter of the fifth line, to the fourth letter of the fourth line, etc.

The second set of material was similar.

In working out this material, the test lines were first equalized in the frequency with which the letter-combinations occurred in common words. A chart was used showing how often each letter in the alphabet is followed by each other letter in the first 2,000 words in the Thorndike Word-Book. Only consonants were used in this material, and only combinations never found in everyday English words. The test lines were also equalized for changes from right to left hand, and, roughly, for difficulty of finger movement. In a preliminary study the equivalence of difficulty of the lines was checked, and the two sets of test material used in the experiment were then chosen from other sets constructed in the same way.

Apparatus.—The materials, typed and mounted on heavy cardboard with three test lines or five practice lines on a card, were held on an adjustable rack which could be placed in a convenient position. The typewriter used was an Underwood Standard. Time was measured by an electric clock controlled by an automatic device so that it began to run as soon as the subject pressed the first key and stopped as soon as the last key was struck. The experimenter watched the clock and recorded the time.

Subjects.—The 40 subjects in Experiment A, 11 men and 29 women, were all students at the University of Wisconsin. Since about half of them were enrolled in the summer session, a number of the subjects were somewhat older than the average student. All were able to use the touch system and could type with some proficiency, but they were not professional typists.

Procedure.—The following procedure was used in Experiment A:

Test 1 (before any practice). 25 repetitions of each of the three test lines.

Practice block (immediately after Test 1). The five lines of the block were typed 35 times.
Test 2 (immediately after practice). Each test line typed 25 times as in Test 1.
Test 3 (following day). Each line typed 25 times as in Tests 1 and 2.

Each test period took approximately half an hour, and the practice block about one hour. Frequent short rest periods were given. The order of presentation of the test lines was rotated. Test 2 and Test 3 followed the same order of rotation and were exactly like Test 1 in procedure for each subject. Test 2 followed immediately after practice; Test 3 was given the next day, approximately 24 hours later.

After the experiment the subjects were questioned as to whether they knew or guessed the purpose of the experiment and whether there had been any disturbing factors in the experimental situation. In preliminary studies it had been found that subjects tended to group the letters in typing. They were therefore also questioned about this, and it was found that of the 40 subjects in Experiment A, 11 answered that they did not group the letters at all. Ten said that they grouped by rhythm of typing, and 19 that they did some artificial grouping, by twos, tnrees, fours, fives, and, in one case, sixes. This grouping done by the subjects seems to the writer important only in that it shows that the learning was definitely serial learning and that the subjects were, as almost always in learning, active and not passive, trying to do something with the material presented to them.

Treatment of Data.—In the treatment of data, the first step was to check typewritten material for errors. Because with this kind of data time and errors are so closely related that time-scores alone are meaningless, we weighted the time-scores for errors. This was done by first dividing the total time for each line by the number of correct responses in it; the quotient obtained was then multiplied by the number of errors, and the product of this was added to the total time. In other words, each score was weighted by adding to the original score the number of errors times the amount of time it took to make one correct response. It was the same thing as multiplying the time for one correct response by the number of responses made, except that the error involved in multiplying the fraction was avoided. All the results, both for test lines and practice block, have been given in terms of these corrected scores.

In summarizing the results statistically, we treated the data of all the subjects together, finding the Q_1, Median, Q_3, Mean, S.D., and P.E.s of the Mean and Median for the 1,000 scores made by the 40 subjects for each test line, the backward, the remote forward skipping one, and the control, in each of the three test periods, before, immediately after, and the day following practice. The significance of the results depends on the differences between the scores made on the control and on the backward line, and between the control and the remote forward line, in the Test 2 and Test 3 measures, the tests following practice.

The practice blocks were also corrected for errors and their scores converted into efficiency scores. The scores for the five lines of each block were added and the scores treated as totals. Distributions of the scores on each of the 35 trials were made, and the Q_1, Median, and Q_3 of these distributions were found. From the median of the first trial to the median of the last trial there was 18 percent of improvement.

It may be said here that the subjects used in this experiment were moderately proficient typists, who could use the touch system but who were not professional typists. The series learned, as pointed out previously, were made up of unusual combinations never found in ordinary words. They therefore presented a new situation which involved a reorganization of motor responses. While the training involved in this learning did not, of course, mean that the subjects learned to type better, it did

mean that the repetition of these series over and over resulted in noticeable improvement in the typing of this particular material. The typing became smoother, and the scores, representing time and errors, became smaller as the subjects typed. This was due not only to improvement in coördination of motor activities but to improvement in all the activities involved in the act. The reading activities, that is the observable processes of following the material without hesitating or losing the place, improved noticeably.

Results and Discussion.—When we examined the data for the subjects in Experiment A, we found that the following results were obtained:

(1) The series of consonants in the test material were very nearly equal in difficulty before the typing of the practice block. This may be seen by examination of the statistical measures summarized in Table I, which presents all the

TABLE I (EXPERIMENT A)

SUMMARY OF STATISTICAL DATA ON TEST MATERIAL

40 subjects typing 3 test lines 25 times each before and after practice. All figures in terms of time in seconds corrected for errors.

Test 1 (Before practice)

	Backward	Remote Forward	Control
N	994	995	995
Q_1	7.03	7.06	7.05
Mdn.±P.E.$_{mdn.}$	8.62±.10	8.63±.10	8.61±.10
Q_3	10.94	11.03	11.20
Av.±P.E.$_{av.}$	9.40±.08	9.67±.08	9.68±.08
S.D.	3.59	3.73	3.69

Test 2 (Following practice after short rest period)

	Backward	Remote Forward	Control
N	997	997	997
Q_1	6.64	6.46	6.75
Mdn.±P.E.$_{mdn.}$	8.01±.07	8.09±.08	8.17±.08
Q_3	9.64	9.89	10.33
Av.±P.E.$_{av.}$	8.54±.06	8.41±.06	8.74±.06
S.D.	2.58	2.91	2.87

Test 3 (20 to 24 hours after Test 1)

	Backward	Remote Forward	Control
N	999	998	999
Q_1	5.85	5.84	6.04
Mdn.±P.E.$_{mdn.}$	7.00±.06	7.05±.06	7.26±.06
Q_3	8.37	8.62	8.88
Av.±P.E.$_{av.}$	7.50±.05	7.49±.05	7.59±.05
S.D.	2.29	2.41	2.28

measures obtained for the three test lines, and by the differences in means and medians between the three lines, presented in Tables II and III. The other measures, the Q_1, Q_3, and

TABLE II (EXPERIMENT A)

MEANS AND DIFFERENCES BETWEEN MEANS BEFORE AND AFTER PRACTICE

	Mean	P.E.$_M$.	Diff. of Means	P.E.$_{diff.}$
Test 1 (Before practice)				
A. Backward	9.40	±.08	C−A=.28	±.11
			(Control minus Backward)	
B. Remote forward	9.67	±.08	C−B=.01	±.11
			(Control minus Remote forward)	
C. Control	9.68	±.08		
Test 2 (Immediately after practice)				
A. Backward	8.54	±.06	C−A=.20	±.08
B. Remote forward	8.41	±.06	C−B=.33	±.09
C. Control	8.74	±.06		
Test 3 (Following day)				
A. Backward	7.50	±.05	C−A=.09	±.07
B. Remote forward	7.49	±.05	C−B=.10	±.07
C. Control	7.59	±.05		

TABLE III (EXPERIMENT A)

MEDIANS AND DIFFERENCES BETWEEN MEDIANS BEFORE AND AFTER PRACTICE

	Mdn.	P.E.$_{mdn.}$	Diff. of Mdns.	P.E.$_{diff.}$
Test 1 (Before practice)				
A. Backward	8.62	±.10	C−A=−.01	±.14
			(Control minus Backward)	
B. Remote forward	8.63	±.10	C−B=−.02	±.14
			(Control minus Remote forward)	
C. Control	8.61	±.10		
Test 2 (Immediately after practice)				
A. Backward	8.01	±.07	C−A=.16	±.10
B. Remote forward	8.09	±.08	C−B=.08	±.11
C. Control	8.17	±.08		
Test 3 (Following day)				
A. Backward	7.00	±.06	C−A=.26	±.08
B. Remote forward	7.05	±.07	C−B=.21	±.09
C. Control	7.26	±.06		

S.D. of the Test 1 scores, shown in Table I, also indicate that the three sequences were equal in difficulty; the curves for the scores on the three lines are almost identical.

On Test 1, before practice, the means were:

Backward	9.40±.08 sec.
Remote forward	9.67±.08 sec.
Control	9.68±.08 sec.

The medians on Test 1 were:

Backward	8.62±.10 sec.
Remote forward	8.63±.10 sec.
Control	8.61±.10 sec.

Because the measures were not exactly identical on Test 1, differences between Test 1 scores and those in Test 2 and Test 3 were summarized in terms of percentage of improvement, using the Test 1 measures as base. These are shown in Table IV.

TABLE IV (EXPERIMENT A)

PERCENTAGE OF IMPROVEMENT IN MEANS AND MEDIANS BEFORE AND AFTER PRACTICE

(Test 1 before practice; Test 2 immediately after practice; Test 3 on following day)

Means		Medians	
Test 1 to Test 2		**Test 1 to Test 2**	
Control	9.71%	Control	5.11%
Backward	9.14%	Backward	7.39%
Backward—Control	−.57%	Backward—Control	2.28%
Test 1 to Test 3		**Test 1 to Test 3**	
Control	21.59%	Control	15.67%
Backward	20.21%	Backward	18.79%
Backward—Control	−1.38%	Backward—Control	3.12%
Test 1 to Test 2		**Test 1 to Test 2**	
Control	9.71%	Control	5.11%
Remote forward	13.09%	Remote forward	6.25%
Remote forward—Control	3.38%	Remote forward—Control	1.14%
Test 1 to Test 3		**Test 1 to Test 3**	
Control	21.59%	Control	15.67%
Remote forward	22.54%	Remote forward	18.30%
Remote forward—Control	1.05%	Remote forward—Control	2.63%

(2) From the median of the first trial to the median of the last trial, there was 18 percent of improvement in speed and accuracy of typing the practice block.

(3) Differences between the three lines on each test are shown in terms of means in Table II and in terms of medians in Table III. If there were backward association, differences between the control and the backward measures would increase from Test 1, before practice, to Test 2, immediately after practice, or from Test 1 to Test 3, on the following day.

Differences between the means of the control and backward lines (Table II) decrease on Tests 2 and 3; differences between the medians of these two lines (Table III) increase. Differences between the means (Control minus Backward) were:

Test 1 ..... .28±.11
Test 2 ..... .20±.08
Test 3 ..... .09±.07

Differences between the medians (Control minus Backward) were:

Test 1 ..... −.01±.14
Test 2 ..... .16±.10
Test 3 ..... .26±.08

The control therefore improved more than the backward, as measured by the means, and slightly less than the backward as measured by the medians. None of these differences, however, is large enough to be significant.

Table IV shows these results in terms of percentage of improvement. As measured by means, improvement from Test 1 to Test 2 was:

Control ..... 9.71 percent
Backward ..... 9.14 percent

From Test 1 to Test 3 the improvement in means was:

Control ..... 21.59 percent
Backward ..... 20.21 percent

The medians show the following percentages of improvement from Test 1 to Test 2:

Control ..... 5.11 percent
Backward ..... 7.39 percent

From Test 1 to Test 3, medians show the following:

Control ..... 15.67 percent
Backward ..... 18.79 percent

None of these differences is large enough to be significant, and within such differences as exist, the means show greater improvement for the control line than for the backward line. It may be concluded, therefore, that the evidence is against backward association.

(4) The difference between the means of the control line (8.74 ± .06) and of the remote forward line (8.41 ± .06) in Test 2 is .33 ± .09 seconds. Among all the results, this is the only difference large enough to be reliable and possibly

significant. But the difference of the medians of these same lines in the same test does not show this result, the difference being only .08 ± .11. In other words, while the means show that the remote forward line improved more following practice than the control line, and consequently the evidence of the means indicates remote association in Test 2, the medians do not show this.

In terms of means, the percentage of improvement from Test 1 to Test 2 was as follows:

Control	9.71 percent
Remote forward	13.09 percent

Improvement in means from Test 1 to Test 3 was:

Control	21.59 percent
Remote forward	22.54 percent

Medians show the following improvement from Test 1 to Test 2:

Control	5.11 percent
Remote forward	6.25 percent

From Test 1 to Test 3, improvement in medians was:

Control	15.67 percent
Remote forward	18.30 percent

The evidence is, therefore, against remote forward association.

(5) There is no evidence that the test 24 hours after practice is better than a test immediately after learning for showing remote association.

III. Experiment B

Experiment B was similar to Experiment A in materials, apparatus, and procedure, except for one aspect of the procedure, the length of practice period. The test lines were typed 40 times in each of the three test periods, before, after, and the day following practice, and the practice block was typed 40 times on six consecutive days and 20 times on the seventh day of practice. Altogether there were 260 repetitions of the practice block by each of the nine subjects.

Results and Discussion.—The principal results of Experiment B are summarized in Tables V, VI, VII, and VIII. They were as follows:

TABLE V (EXPERIMENT B)

SUMMARY OF STATISTICAL DATA ON TEST MATERIAL

9 subjects typing 3 test lines 40 times each before and after practice. All figures in terms of time in seconds corrected for errors.

Test 1 (Before practice)

	Backward	Remote Forward	Control
N	360	358	360
Q_1	5.96	6.03	6.15
Mdn.±P.E.$_{mdn.}$	7.40±.12	7.25±.11	7.58±.11
Q_3	9.18	9.05	9.37
Av.±P.E.$_{av.}$	7.98±.10	7.80±.09	7.92±.09
S.D.	2.78	2.53	2.57

Test 2 (Following practice after short rest period)

N	360	360	360
Q_1	5.12	5.03	5.00
Mdn.±P.E.$_{mdn.}$	6.38±.09	6.25±.09	6.33±.08
Q_3	7.78	7.81	7.63
Av.±P.E.$_{av.}$	6.56±.06	6.59±.08	6.51±.07
S.D.	1.69	2.11	1.86

Test 3 (24 hours after Test 2)

N	360	360	360
Q_1	4.02	4.24	4.19
Mdn.±P.E.$_{mdn.}$	5.17±.08	5.28±.07	5.23±.06
Q_3	6.76	6.65	6.25
Av.±P.E.$_{av.}$	5.35±.06	5.49±.06	5.28±.05
S.D.	1.71	1.58	1.44

TABLE VI (EXPERIMENT B)

MEANS AND DIFFERENCES BETWEEN MEANS BEFORE AND AFTER PRACTICE

Test 1 (Before practice)

	Mean P.E.$_M$.	Diff. of Means P.E.$_{diff.}$
A. Backward	7.98±.10	C−A=−.06±.13 (Control minus Backward)
B. Remote forward	7.80±.09	C−B= .12±.12 (Control minus Remote forward)
C. Control	7.92±.09	

Test 2 (Immediately following practice)

	Mean P.E.$_M$.	Diff. of Means P.E.$_{diff.}$
A. Backward	6.56±.06	C−A=−.05±.09
B. Remote forward	6.59±.08	C−B=−.08±.11
C. Control	6.51±.07	

Test 3 (Following day)

	Mean P.E.$_M$.	Diff. of Means P.E.$_{diff.}$
A. Backward	5.35±.06	C−A=−.07±.08
B. Remote forward	5.49±.06	C−B=−.21±.08
C. Control	5.28±.05	

TABLE VII (EXPERIMENT B)

MEDIANS AND DIFFERENCES BETWEEN MEDIANS BEFORE AND AFTER PRACTICE

Test 1 (Before practice)	Mdn.	$P.E._{mdn.}$	Diff. of Mdns.	$P.E._{diff.}$
A. Backward	7.40	±.12	C−A=.18	±.16
			(Control minus Backward)	
B. Remote forward	7.25	±.11	C−B=.33	±.16
			(Control minus Remote forward)	
C. Control	7.58	±.11		
Test 2 (Immediately after practice)				
A. Backward	6.38	±.09	C−A=−.05	±.12
B. Remote forward	6.25	±.09	C−B= .08	±.12
C. Control	6.33	±.08		
Test 3 (Following day)				
A. Backward	5.17	±.08	C−A= .06	±.10
B. Remote forward	5.28	±.07	C−B=−.05	±.09
C. Control	5.23	±.06		

TABLE VIII (EXPERIMENT B)

PERCENTAGE OF IMPROVEMENT IN MEANS AND MEDIANS BEFORE AND AFTER PRACTICE

(Test 1 before practice; Test 2 immediately after practice; Test 3 on following day)

Means		Medians	
Test 1 to Test 2		**Test 1 to Test 2**	
Control	17.80%	Control	16.49%
Backward	17.79%	Backward	13.78%
Backward—Control	−.01%	Backward—Control	−2.71%
Test 1 to Test 3		**Test 1 to Test 3**	
Control	33.33%	Control	31.00%
Backward	32.95%	Backward	30.13%
Backward—Control	−.38%	Backward—Control	−.87%
Test 1 to Test 2		**Test 1 to Test 2**	
Control	17.80%	Control	16.49%
Remote forward	15.51%	Remote forward	13.79%
Remote forward—Control	−2.29%	Remote forward—Control	−2.70%
Test 1 to Test 3		**Test 1 to Test 3**	
Control	33.33%	Control	31.00%
Remote forward	29.61%	Remote forward	27.17%
Remote forward—Control	−3.72%	Remote forward—Control	−3.83%

(1) The test series were again practically equal in difficulty before the practice period.

(2) Because of the longer practice period, the improvement in typing the practice block was considerably greater than in Experiment A. From the median of the first to the median of the last trial of the practice block, there was

44 percent of improvement in comparison with the 18 percent in Experiment A.

(3) All the statistical measures for Experiment B are summarized in Table V, which is the equivalent of Table I for Experiment A. The differences between the test lines in Experiment B are shown in Tables VI and VII.

Table VI shows that the differences between the control and backward lines are practically identical on all three tests as measured by means. Table VII shows that the differences between the control and backward decrease somewhat as measured by medians. The control and backward improved almost the same amount judged by both measures.

Differences between the means (Control minus Backward) were:

Test 1	$-.06\pm.13$
Test 2	$-.05\pm.09$
Test 3	$-.07\pm.08$

Differences between the medians (Control minus Backward) were:

Test 1	$.18\pm.16$
Test 2	$-.05\pm.12$
Test 3	$.06\pm.10$

The percentage of improvement (Table VIII) shows the same results. From Test 1 to Test 2, improvement as measured by means was:

Control	17.80 percent
Backward	17.79 percent

Improvement in means from Test 1 to Test 3:

Control	33.33 percent
Backward	32.95 percent

Medians show the following improvement from Test 1 to Test 2:

Control	16.49 percent
Backward	13.78 percent

From Test 1 to Test 3 the improvement in medians was:

Control	31.00 percent
Backward	30.13 percent

In summary, it is clear that the evidence of Experiment B is definitely against backward association.

(4) The evidence from percentages of improvement (Table VIII) indicates that the control line improved more than the

remote forward line on both of the tests following practice. The evidence is clearly against remote forward association. Improvement from Test 1 to Test 2, as measured by means, was:

Control	17.80 percent
Remove forward	15.51 percent

Improvement in means from Test 1 to Test 3:

Control	33.33 percent
Remote forward	29.61 percent

Improvement from Test 1 to Test 2, as measured by medians:

Control	16.49 percent
Remote forward	13.79 percent

As measured by medians, improvement from Test 1 to Test 3 was:

Control	31.00 percent
Remote forward	27.17 percent

In Experiment A there was a slight advantage, too small to be significant, for the remote forward line in the tests after practice. The one possibly significant difference was that between the means of the control and remote forward line on Test 2, which was $.33 \pm .09$ seconds. In the results of Experiment B, we find that the control line improved slightly more than the remote forward line. Differences between the means (Control minus Remote Forward) were as follows:

Test 1	$.12 \pm .12$
Test 2	$-.08 \pm .11$
Test 3	$-.21 \pm .08$

Differences between the medians (Control minus Remote Forward) were:

Test 1	$.33 \pm .16$
Test 2	$.08 \pm .12$
Test 3	$-.05 \pm .09$

Here again, the differences are too small to be significant, but they are significant in comparison with the results of Experiment A, in showing that further practice did not increase the slight advantage of the remote forward line over the control line, but rather reversed the slight difference.[2]

There is no evidence for inhibition or habit interference in these data. It will be remembered that Test 1 came

[2] This confirms the findings of Cason (3, pp. 313, 316–17).

before practice, was followed by practice, and then by Test 2. Test 3 was given on the following day without further practice. If the practice had interfered with the test series, it would be natural to suppose that Test 2 would show higher time scores than Test 1. This was not true; there was a decided improvement from Test 1 to Test 2, which immediately followed the practice.

IV. General Conclusions and Summary

The activity and the kind of learning involved in the present study were such that the subjects were not tempted to look back over the lines. They had no insight into the problem, did not recognize reversed material, and since we had no retest in which the subjects had to recall the sequence, they did not use memory review. Our results agree with those of previous investigators in suggesting that the less insight on the part of the subjects and the less memorizing activity involved, the less remote association is found. Our conclusions did not confirm those of Hall (**8**) as to the importance of time of retest. No more evidence was found in a test 24 hours after practice than in the test immediately after it. The results also showed that a longer practice period did not result in evidence for remote association.

This experiment strongly indicates that there is no remote association if that phrase is taken to mean that when A, B, C, and D are present in a series learned by the subject, A and C, items separated in the series, somehow become connected or B and A, in backward order, become connected by virtue of their temporal sequence. On the other hand, if we were to ignore the evidence from many earlier studies that subjects are generally active in the learning process and that in almost every type of learning situation they may create internal contiguity by ideational activity, we would falsify the situation. This evidence strongly suggests that any theory which attempts to explain all learning in terms of simple external relations of stimuli and responses is inadequate. When, however, ideational activities are kept at a minimum, as in this experiment, no remote forward or backward association is found.

Summary.—In the present study of remote association in serial learning we have used the typing of a series of consonants, measuring the amount of learning by improvement in speed and accuracy. The nature of the material was such that the subjects were not tempted to glance backward or skip forward, and the testing method was such that they did not think through the material in uncontrolled rehearsals.

Three meaningless series of consonants, made equal in difficulty, were used as test material. One of these, the backward line, was reversed in the practice material; the remote forward series was presented in skipping-one order, that is, with an interpolated letter between each consonant. The control series was present in a random order.

Three tests, exactly alike in procedure, were given: Test 1, before practice, Test 2, immediately after practice, and Test 3, approximately 24 hours later. The two tests were given to check the importance of time of retest.

Significance of the degree of learning was studied by using two experimental procedures, Experiment A and Experiment B, exactly alike except for amount of practice. In Experiment A, practice material was repeated 35 times, taking about one hour; in Experiment B, it was repeated 260 times, taking about nine hours of practice distributed throughout a week. Forty subjects were used in Experiment A and nine in Experiment B.

The following results were found:

(1) There was no evidence for backward or remote forward association in either Experiment A or B. In Experiment A slight differences between the control and remote forward lines on the tests after practice were in the direction of remote forward association, though the differences were not large enough to be significant. In Experiment B, with a longer practice period, the control improved more than either the backward or the remote forward line on tests following practice.

(2) Negative results were found both on the test immediately after practice and on the test given 24 hours later.

There is therefore no reason for assuming that time of retest was of importance in this experiment.

(3) A longer practice period did not result in evidence for backward or remote forward association.

(Manuscript received November 29, 1937)

References

1. Cason, H., The concept of backward association, *Amer. J. Psychol.*, 1924, **35**, 217–229.
2. Cason, H., Specific serial learning; a study of backward association, *J. Exper. Psychol.*, 1926, **9**, 195–227.
3. Cason, H., Specific serial learning; a study of remote forward association, *J. Exper. Psychol.*, 1926, **9**, 299–324.
4. Ebbinghaus, H., *Memory; a contribution to experimental psychology*, 1885, tr. 1913 by Ruger, H. A. and Bussenius, C. E.
5. Garrett, H. E., and Hartmann, G. W., An experiment on backward association in learning, *Amer. J. Psychol.*, 1926, **37**, 241–246.
6. Guthrie, E. R., Association as a function of time interval, *Psychol. Rev.*, 1933, **40**, 355–367.
7. Guthrie, E. R., *The psychology of learning*. 1935.
8. Hall, M. E., Remote associative tendencies in serial learning, *J. Exper. Psychol.*, 1928, **11**, 65–76.
9. Hermans, T. G., A study of the relative amounts of forward and backward association of verbal material, *J. Exper. Psychol.*, 1936, **19**, 769–775.
10. Lepley, W. M., A theory of serial learning and forgetting based upon conditioned reflex principles, *Psychol. Rev.*, 1932, **39**, 279–288.
11. Lepley, W. M., Serial reactions considered as conditioned reactions, *Psychol. Monog.*, 1934, **46**, No. 205, 1–56.
12. Müller, G. E., and Pilzecker, A., Experimentelle Beiträge zur Lehre vom Gedächtniss, *Zeit. f. Psychol. u. Physiol. d. Sinnesorgane*, 1900, Erganzungsband **1**, 1–288.
13. Müller, G. E., and Schumann, F., Experimentelle Beiträge zur Untersuchung des Gedächtnisses, *Zeit. f. Psychol. u. Physiol. d. Sinnesorgane*, 1894, **6**, 81–190 and 257–339.
14. Münsterberg, H., Die Association successiver Vorstellungen, *Zeit. f. Psychol. u. Physiol. d. Sinnesorgane*, 1890, **1**, 99–107.
15. Wohlgemuth, A., On memory and the direction of associations, *Brit. J. Psychol.*, 1913, **5**, 447–465.
16. Wohlgemuth, A., Simultaneous and successive association, *Brit. J. Psychol.*, 1914, **7**, 434–452.

EXPERIMENTAL STUDIES IN ROTE-LEARNING THEORY. II. REMINISCENCE WITH VARYING SPEEDS OF SYLLABLE PRESENTATION

BY CARL IVER HOVLAND

Department of Psychology, Institute of Human Relations, Yale University [1]

Introduction

Reminiscence of the type obtained by Ward (**19**) is much more pronounced when the learning has been by massed practice than when it has been by distributed practice, with two minutes of color-naming between trials (Hovland, **9**). This finding is in accord with the predictions based upon our mathematico-deductive theory of rote-learning (Hull, Ross, Perkins, and Hovland, **15**). The interesting question arises as to the generality of this result—whether reminiscence is also diminished when other methods of decreasing intra-serial 'inhibition' [2] are employed. One such method involves the use of paired-associates (**10**, **12**). Another method is the presentation of the syllables in the series at a slower rate than the two-second speed customarily employed. This latter technique results in a marked decrease in the number of failures in the central portions of the serial lists. The reduction in difficulty is even more pronounced than that obtained with distributed practice between successive trials (Hovland, **11**, **13**).

The present study employs the second method of approach by comparing the reminiscence phenomenon following learning by massed practice with two speeds of syllable presentation, a two-second and a four-second rate. The results obtained

[1] This is the second in a series of studies by the writer on the experimental investigation of implications of a mathematico-deductive theory of rote learning developed in a forthcoming monograph by Hull, Ross, Perkins, and Hovland (**15**). The writer wishes to thank Professor Clark L. Hull for his support of the work.

[2] For discussion concerning the writer's use of the concept 'inhibition' see footnote 2 in previous article (**9**).

will shed additional light upon our general theorem that *as the magnitude of inhibition at the termination of practice decreases, other things being equal, the magnitude of the difference in effective strength of the excitatory tendencies at the termination of learning and at the post-learning maximum will decrease.* Other deductions based upon our theory will be discussed in relation to incidental findings.

Experimental Procedure

The principal results of the experiment are derived from a comparison of retention with and without a two-minute rest pause following learning with two-second and with four-second rates of syllable presentation. On any particular day one of the following six experimental programs was involved:

I. *Learning to one perfect recitation with the* TWO-SECOND *rate of presentation.*—Here the subjects learned by massed practice to mastery without interruption.

II. *Learning to the criterion of seven syllables correct with the* TWO-SECOND *rate, introduction of rest-pause, continuation of learning to one perfect recitation.*—Immediately after the trial on which the subject correctly anticipated seven or more syllables, the shutter at the window where the syllables were exposed was closed and the shutter exposing the colors was opened. After two minutes of color-naming this shutter was closed, and the syllable shutter reopened. The subjects then continued the learning by massed practice until mastery.

III. *Learning to one perfect recitation with the* FOUR-SECOND *rate of presentation.*—This was identical with Program I except for the four-second rate of presentation.

IV. *Learning to criterion of seven syllables correct with* FOUR-SECOND *rate, introduction of rest pause, continuation of learning to one perfect recitation.*—This was identical with Program II, except for the four-second rate of presentation.

Half of the cases in Groups I and III continued to a second perfect recitation immediately, while the remaining half named colors for two minutes and then continued to a second perfect recitation. This procedure permitted comparison of the reminiscence effect following learning to mastery with the two speeds of presentation.

To compare the effects of the rest pause following a single recitation of the list, two additional programs were employed:

V. *Single presentation of list at* TWO-SECOND *rate, recall two minutes later.*—Between the presentation of the list and the recall the subjects named colors as in Programs II and IV.

VI. *Single presentation of list at* FOUR-SECOND *rate, recall two minutes later.*—This was identical with Program V except for the four-second rate of presentation.

Comparisons could thus be made between recall scores obtained in Program V and those obtained on the first trials of Programs I and II, and between the recall scores in Program VI and the ones obtained on the first trials of Programs III and IV.

The conditions of the experiment and the general procedure and instructions were identical with those of the previous study (**9**). The syllables were learned serially by the anticipation method. During the rest pauses colored strips mounted on the bands were named as presented. This activity obviated rehearsal. The experiments were performed in a sound-proof room.

Sixteen bands, containing twelve syllables and a cue symbol each, were prepared. The bands were arranged so that each series had the same mean and average deviation

in association frequency. Successive pairs of syllables had approximately the same sum of association frequencies. Rotation of the syllables in the series was employed (*cf.* 14). The standard rules for construction of lists were observed.

Half of the series was presented at the rate of one syllable every two seconds, and half at the rate of one every four seconds. The pause between trials was maintained at eight seconds for both speeds of syllable presentation.

Thirty-two Yale College students paid for their services were subjects. The purpose of the experiment was unknown to them. The subjects performed their learning at the same time every day except Sunday for sixteen days. Completely counterbalanced practice equilibration was employed. Each subject began with a different list, and each type of program was represented equally in each practice position during learning. To keep the subjects' attitude in learning as constant as possible the subjects were not told in advance the rate at which the syllable would be presented.

Only four practice days were required because the subjects had been brought to a high practice level by previous experimentation. During the practice sessions each of the first four programs was employed to give the subject familiarity with the procedure involved. During the practice at the four-second rate the importance of avoiding repetition of the associations by rehearsal was stressed.

Results

Effect of Speed of Syllable Presentation upon Distribution of Failures in Various Serial Positions.—If the four-second presentation of the syllables is effective in reducing intra-serial inhibition, this fact should be reflected in a greater reduction of failures to respond correctly in the central than in the end serial positions. Demonstration of this effect is shown in Fig. 1. Here are presented the mean number of failures in each syllable position during the learning to a criterion of seven syllables correct with the two-second and with the four-second rate. The curve with the four-second presentation shows a reduction in difficulty over that of the two-second speed, which is most marked in the central portions.

The decrease in difficulty brought about by the four-second presentation is indicated by the fact that after comparable amounts of practice the mean number of trials to obtain seven syllables correct was 6.05 at the two-second rate and 3.28 at the four-second speed. The difference is highly reliable statistically. The efficacy of increasing the time of exposure of the syllables is greater with the anticipation method of learning than with other methods (**5, 11, 16**).[3]

[3] Introspections indicated no violations of the instructions forbidding rehearsal of the list during the learning at the slower rate. Typical was the comment of one

Our results on this point are in agreement with the studies of Ebbinghaus (4), Ogden (18), Gamble (7) and others. Calculations from the data presented by Gamble based upon four subjects (pages 120 and 126) show that 8.5 trials were required to learn the lists of nonsense syllables at the one-second presentation but only 4.6 at the four-second rate. A psychophysical function showing the relationship between speed of presentation and strength of association has been

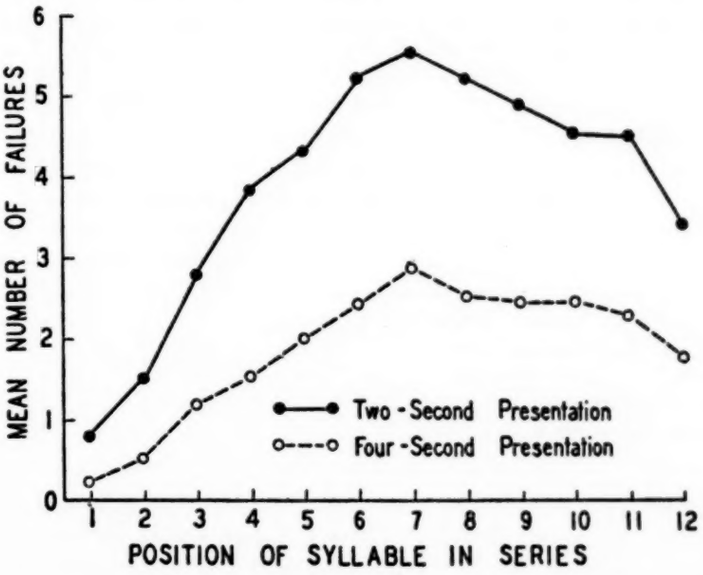

FIG. 1. Composite graphs showing number of failures in each syllable position made during learning to a criterion of 7 syllables correct with 2-second and 4-second rates of presentation. Each point is based upon the mean of 128 determinations. Failures are computed beginning with the first trial on which the subjects attempt recall, *i.e.* the second rotation of the drum.

determined by Ernst, Smith, Moessner, Rudisill, and Atwater (6).

Reminiscence at Three Stages of Learning with Two-second and Four-second Rates of Presentation.—To secure tests of reminiscence at three typical stages of learning, the points chosen were (1) after one presentation of the list, (2) following the attainment of seven syllables correct, and (3) following the first perfect recitation. In Table 1 results are presented to show retention *following one presentation* of the entire list when the syllables are presented at the two-second and four-

subject: "I don't think over the words but they seem to come so much easier; I don't have to strain at all to get the syllables."

TABLE 1

RETENTION FOLLOWING ONE PRESENTATION OF NONSENSE-SYLLABLE SERIES AT 2-SECOND AND 4-SECOND RATE WITH AND WITHOUT 2-MINUTE REST PAUSE BETWEEN PRESENTATION AND RECALL. 32 SUBJECTS

(A) Recall Scores

	2-second Rate		4-second Rate	
	Mean	P.E.$_{M.}$	Mean	P.E.$_{M.}$
No. syll. recalled immediately after presentation...	1.79	.071	2.81	.130
No. syll. recalled 2 minutes after presentation.....	2.10	.082	2.52	.121
Difference.....	.31		.29	
P.E.$_{diff.}$*.....	.058		.098	
Critical ratio$_{P.E.}$.....	5.34		2.96	

(B) Subjects Showing Reminiscence

	Percent	P.E.$_{P.}$	Percent	P.E.$_{P.}$
1. Subjects recalling more syllables following 2-min. pause than immediately.....	56.3	.059	34.4	.057
2. Subjects recalling same number.....	12.5	.039	18.7	.047
3. Subjects recalling fewer.....	31.2	.055	46.9	.059
Difference between 1 and 3.....	25.1		12.5	

* The formula for the P.E.$_{diff.}$ which involves the correlation of the two sets of data was employed where permissible. These P.E.$_{diff.}$ will be indicated by an asterisk (*). The correlations were obtained after pooling the determinations for each subject, thus eliminating practice effects during the successive cycles.

second rates. When the two-second rate is employed there is an improvement in recall scores with the passage of time which is statistically reliable (C.R.$_{P.E.}$ = 5.34). This is in accord with previous results (Ward, **19**; Hovland, **9**). When the series is presented at the four-second rate, reminiscence does not occur. Instead, there is a loss with the passage of time, although it is not statistically reliable (C.R.$_{P.E.}$ = 2.96). The difference in the amount of change in recall score with the two rates is reliable (C.R.$_{P.E.}$ = 5.26). Similar results are shown in the data concerning the number of subjects showing reminiscence. While more subjects show improvement than decrement in recall with the two-second rate, the converse tends to be true with the four-second presentation.

The reminiscence data obtained following the trial on which *seven syllables were correctly anticipated* are given in

Table 2. The comparability of the groups before the rest pause is indicated below:

Procedure	No. Syll. Correctly Anticipated on Criterion Trial
Two-second presentation	
1. With rest pause	7.52
2. Without rest pause	7.48
Four-second presentation	
1. With rest pause	7.88
2. Without rest pause	7.94

TABLE 2

RETENTION WITH AND WITHOUT 2-MINUTE REST PAUSE FOLLOWING LEARNING TO CRITERION OF 7 SYLLABLES CORRECT WITH 2-SECOND AND 4-SECOND RATES OF SYLLABLE PRESENTATION. 32 SUBJECTS

(A) Recall

	2-second Rate		4-second Rate	
	Mean	$P.E._{M.}$	Mean	$P.E._{M.}$
Syll. recalled, no rest pause after crit. trial	7.02	.113	8.76	.082
Syll. recalled, 2-min. rest pause after crit. trial	7.53	.122	8.30	.108
Difference	.51		.46	
$P.E._{diff.}$*	.147		.128	
Critical ratio $_{P.E.}$	3.47		3.58	
	Percent	$P.E._{P.}$	Percent	$P.E._{P.}$
1. Subjects recalling more syll. following 2-min. pause than immed.	65.6	.057	28.1	.053
2. Subjects recalling same number	15.6	.044	12.5	.039
3. Subjects recalling fewer	18.8	.047	59.4	.059
Difference between 1 and 3	46.8		31.3	

(B) Relearning to 7 Correct

	Mean	$P.E._{M.}$	Mean	$P.E._{M.}$
Trials required to relearn to 7 correct, no rest pause after crit. trial [1]	.563	.056	.125	.029
Trials required to relearn to 7 correct, 2-min. rest pause after crit. trial	.063	.080	.094	.025
Difference	.500		.031	
$P.E._{diff.}$*	.065		.034	
Critical ratio $_{P.E.}$	7.69		0.91	
	Percent	$P.E._{P.}$	Percent	$P.E._{P.}$
1. Subjects requiring fewer relearning trials following 2-min. pause than immed.	40.6	.059	18.7	.047
2. Subjects requiring same number	53.2	.059	65.7	.057
3. Subjects requiring more	6.2	.028	15.6	.044
Difference	34.4		3.1	

TABLE 2.—(*Continued*)

(C) Trials Required to Proceed from 7 Correct to Mastery

	Mean	P.E.$_{M.}$	Mean	P.E.$_{M.}$
Trials required to learn to mastery from 7 syll., no rest pause after crit. trial	9.05	.451	2.64	.082
Trials required to learn to mastery from 7 syll., 2-min. rest pause after crit. trial	5.00	.211	2.38	.116
Difference	4.05		.26	
P.E.$_{diff.}$*	.364		.115	
Critical ratio$_{P.E.}$	11.13		2.26	
	Percent	**P.E.$_{P.}$**	**Percent**	**P.E.$_{P.}$**
1. Subjects requiring fewer trials to learn to mastery following 2-min. pause than immed.	71.9	.053	53.2	.059
2. Subjects requiring same number	15.6	.043	15.6	.043
3. Subjects requiring more	12.5	.039	31.2	.055
Difference	59.4		22.0	

[1] In computing number of trials required for relearning, the final criterion trials are omitted throughout the paper.

The more rapid learning with the four-second presentation is reflected in higher scores on the criterion trial, since more of the subjects go from a point of less than seven syllables correct to one of more than seven correct of a single trial.

An improvement in recall is obtained when the syllables are presented at the two-second rate. When, however, the syllables are learned at the four-second rate, there is a loss, similar to the case following one presentation. The same difference is obtained when the results are given in terms of the number of subjects showing improvement or decrement. When reminiscence is measured in terms of number of trials required to relearn to the criterion of seven correct, both the two-second and four-second presentations show greater retention after two minutes, but the effect is much more marked in the case of the former. The same result is obtained when the data are computed for the number of subjects showing reminiscence.

A marked reduction in the number of trials required to achieve mastery from the criterion trial of seven correct follows the introduction of the two-minute period when the syllables are presented at the two-second rate. In the case

of the four-second presentation, the saving is much smaller, and the difference between the percentage of subjects showing improvement and the percentage showing decrement is decreased.

Comparison of the efficacy of the two-minute rest pause with the two rates is made in Figs. 2 and 3. Fig. 2 gives the number of trials to learn various numbers of syllables with and without rest pause when the two-second rate is

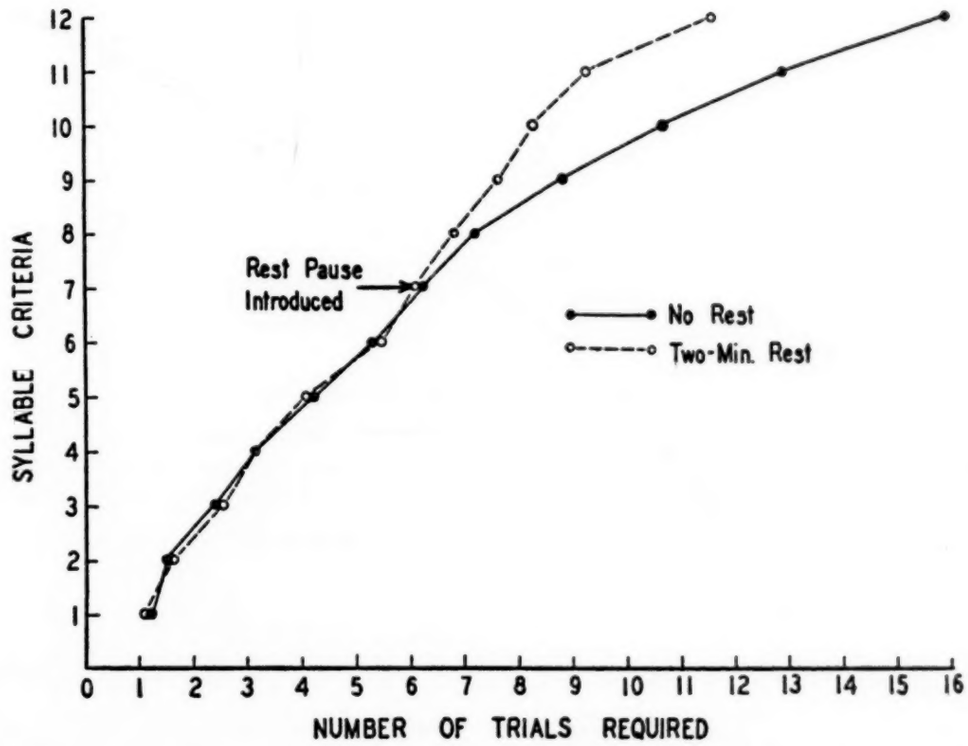
SYLLABLE CRITERIA
NUMBER OF TRIALS REQUIRED
Rest Pause Introduced
No Rest
Two-Min. Rest
0 1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16
1 2 3 4 5 6 7 8 9 10 11 12

FIG. 2. Composite curves showing average number of repetition of list required to learn varying numbers of syllables presented at *2-second intervals*, with and without a 2-minute rest pause following the attainment of 7 syllables correct. Each point is based upon the mean of 64 learning scores.

employed. The results confirm those previously reported by the writer (9) in showing a temporary cessation of the negative acceleration of learning following the introduction of the rest pause. The effect is much less apparent when the four-second presentation is used (Fig. 3).

The difference between the two rates of presentation in their effect upon reminiscence can be seen very clearly in Figs. 4 and 5. In Fig. 4 the numbers of failures to respond correctly made in each syllable position during the learning

from seven syllables correct to twelve correct are plotted for the two-second presentation with and without the two-minute rest pause. The two-minute pause brings about a marked reduction in number of failures, principally in the central portion of the series as is predicted by the theory. The two-minute pause is much less effective in reducing the difficulty of the central portion when the four-second presentation is employed (Fig. 5).

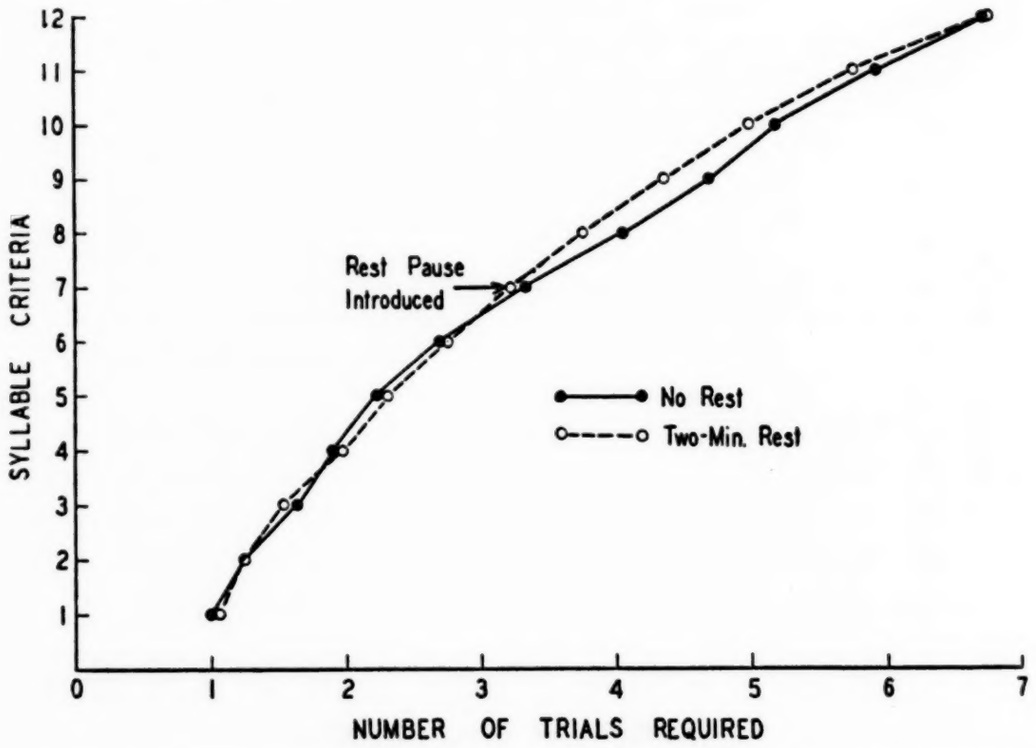

FIG. 3. Composite curves showing average number of repetitions of list required to learn varying numbers of syllables presented at *4-second intervals* with and without a 2-minute rest pause following the attainment of 7 syllables correct. Each point is based upon the mean of 64 learning scores.

Recall and relearning scores with and without the rest pause *following mastery* are presented in Table 3. There is an increase in the number of syllables recalled following the two-minute pause when the two-second presentation is employed, but a decrease with the four-second rate. The same trend is observed in the data concerning the number of subjects showing reminiscence. Relearning to mastery is more rapid when the two-minute pause is introduced following learning at the two-second rate, but not when the four-second rate is employed.

A comparison of a six-second rate of presentation with the four-second and two-second rates has been made in an unpublished study of the writer. The data strongly suggest that the difference between the two-second and four-second

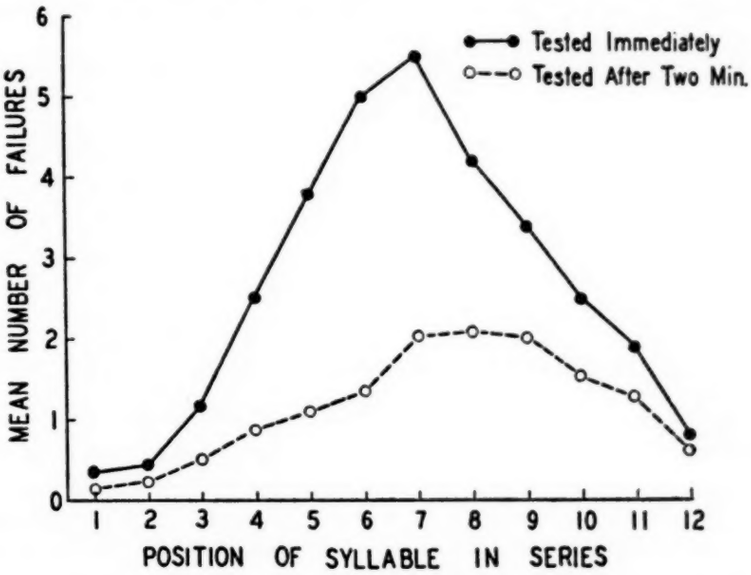

FIG. 4. Composite curves showing mean number of failures in various syllable positions on trials between the one on which 7 and the one on which 12 syllables were correctly anticipated, with and without rest pause following attainment of 7 syllables correct when syllables have been presented at *2-second rate*.

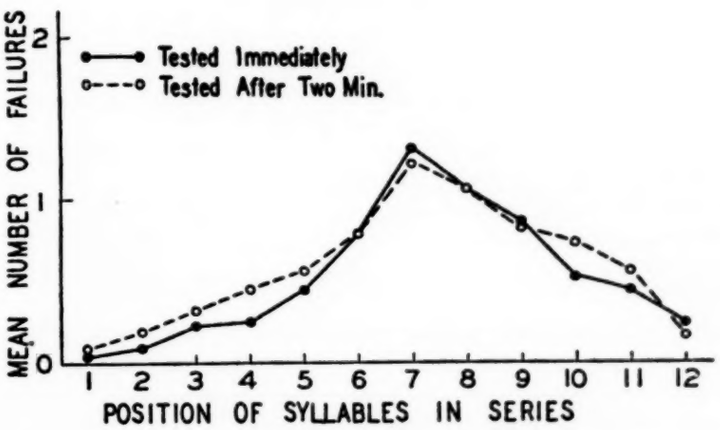

FIG. 5. Composite curves showing mean number of failures in various syllable positions on trials between the one on which 7 and the one on which 12 syllables were correctly anticipated, with and without rest pause following attainment of 7 syllables correct when syllables have been presented at *4-second rate*.

rates with respect to speed of learning, curve of failure, and reminiscence phenomena, is much greater than that between the four-second and six-second rates. It is probable that the

speeds below the two-second rates would be extremely critical for the relationships mentioned.

TABLE 3

RETENTION WITH AND WITHOUT 2-MINUTE REST PAUSE FOLLOWING FIRST PERFECT RECITATION TRIAL WITH 2-SECOND AND 4-SECOND RATES OF SYLLABLE PRESENTATION. 32 SUBJECTS

(A) Recall

	2-second Rate		4-second Rate	
	Mean	P.E.$_{M.}$	Mean	P.E.$_{M.}$
No. syll. recalled immed. after first perfect recitation	11.19	.091	11.75	.060
No. syll. recalled 2 min. after first perfect recitation	11.56	.087	11.58	.063
Difference	.37		0.17	
P.E.$_{diff.}$*	.109		.085	
Critical ratio	3.40		2.00	
	Percent	P.E.$_{P.}$	Percent	P.E.$_{P.}$
1. Subjects who recalled more syllables following 2-min. pause than immediately	34.4	.057	18.7	.047
2. Subjects who recalled the same number	56.2	.059	59.4	.059
3. Subjects who recalled fewer	9.4	.034	21.9	.049
Difference	25.0		3.2	

(B) Relearning

	Mean	P.E.$_{M.}$	Mean	P.E.$_{M.}$
No. trials to relearn to mastery without rest pause following first perfect recitation	0.79	.113	0.25	.071
No. trials to relearn to mastery with 2-minute rest pause after first perfect recitation	0.40	.098	0.25	.072
Difference	.39		—	
P.E.$_{diff.}$*	.129		.110	
Critical ratio	3.02		—	
	Percent	P.E.$_{P.}$	Percent	P.E.$_{P.}$
1. Subjects who required fewer relearning trials following 2-minute pause than immediately	37.5	.057	18.7	.047
2. Subjects who required same number	50.0	.059	62.5	.057
3. Subjects who required more	12.5	.039	18.7	.047
Difference between 1 and 3	25.0		—	

DISCUSSION

The diverse theories which have been advanced to explain reminiscence phenomena have been discussed in an earlier

paper of the writer (**9**). The five principal theories seek to explain reminiscence as a result of (1) Rehearsal, (2) Perseveration, (3) Fatigue, (4) Motivation, or (5) Removal of inhibition.

As in the previous experiment *rehearsal* was ruled out as an explanation by the introduction of color-naming during the rest intervals.

It is difficult to get crucial data concerning an explanation in terms of *perseveration* (**17**) and neural growth (**1**). As Ward (**19**) points out, the color-naming activity would be expected to disrupt the setting-in process demanded by these theories. But, on the other hand, "if by definition this 'setting in' is to be hindered only by those activities after which forgetting can be demonstrated, then of course no evidence of this sort is any test of the theory" (p. 96). For perseveration to explain the difference between the amounts of reminiscence with the two rates of presentation, it must be shown that the perseverative tendencies are heightened by rapid repetition, as contended by Ephrussi (**5**). Indirect evidence against this point is afforded by the experiments of Gamble (**7**). She compared the retention of lists learned by rapid and slow rates of presentation. She assumed that if the series rapidly repeated are more quickly forgotten than those learned at a slow rate "it may be inferred that the final recitation was accomplished in virtue of rather weak associations eked out by perseverative . . . tendencies" (p. 146). She was forced to conclude that ". . . it cannot possibly be inferred from these experiments both that quickly repeated series are remembered less well than slowly repeated series and also that their poorer retention is due to the fact that in the first learning the final recitation was achieved with the aid of perseveration. For, in the first place, in the only clear and well-substantiated case in which series presented fast were not so well remembered as series presented slowly . . . the slow rate of recitation chosen by the subject precludes the possibility that perseveration played a significant part. And, in the second place, we find that in those cases in which we may be pretty sure that the 'mental echo' was present in

the case of the rapidly repeated series, they were better remembered than those slowly repeated" (pp. 146–147).

Reminiscence has also been explained as due to recovery from *fatigue* (**3**, p. 367). If the term 'fatigue' is properly restricted to physical fatigue, it would be necessary, in order to explain the greater reminiscence with the rapid presentation, to show that the rapid rate of presentation produced greater fatigue. This very point has already been investigated by Curtis (**2**). Extraneous tests of fatigue were made, using dynamometer, reaction time, and arithmetic performance. The intrinsic criterion of fatigue was a change in the number of repetitions required for memorization. The results, while indecisive, showed that the rate of presentation had little effect upon the degree of fatigue. As pointed out before (**9**), the pronounced reminiscence after a single presentation of the list at the more rapid rate is good evidence against fatigue as an adequate explanation. The same arguments apply to an explanation based upon changes in *motivation* (*cf.* **3**, **9**).

Removal of inhibition has already been discussed as an explanation in the introductory section of this paper. The principal difficulty with this explanation is the fact that we know so little at present as to the nature of this inhibition. Extensive investigations directed at this problem could profitably be undertaken.

The present results do permit us to associate reminiscence with the same factors that produce an accumulation of difficulty in the central serial positions ('intra-serial inhibition'). Procedures which reduce this difficulty, involving either distribution of practice (with lapse of time between successive presentations of the entire series) or slow rates of presentation (with longer intervals between successive members of the series) produce decreases in reminiscence.

Summary and Conclusions

1. Thirty-two highly practiced subjects learned lists of twelve nonsense syllables by the anticipation method, at two speeds of presentation, two-second and four-second rates.

Following three degrees of learning, the reminiscence phenomenon was studied for the two speeds of presentation, by comparison of recall and relearning with and without a two-minute period of color-naming.

2. The number of trials required for learning was much smaller with the four-second than the two-second rate. This is in accord with previous investigations.

3. The reduction of the number of failures in the various serial positions with the four-second rate of presentation as compared with the two-second speed was most pronounced in the middle and least at the ends.

4. Following a *single presentation* of the entire list of syllables at the two-second rate there was a reminiscence effect, *i.e.*, more syllables were remembered after two minutes of color-naming than immediately following learning. With the four-second rate of presentation fewer syllables were recalled after two minutes than immediately following learning.

5. When learning at the two-second rate was carried on to the criterion of *seven out of twelve syllables correct*, the introduction of a rest pause improved recall, decreased relearning trials, and resulted in fewer trials to go from the criterion of seven syllables correct to mastery. The effect appears to reduce temporarily the negative acceleration of the learning process. Reminiscence under these conditions was much reduced with the four-second presentation, the recall scores being actually lower following the rest pause.

6. Following the *first perfect recitation trial*, the introduction of the rest pause served to improve both relearning and recall when the learning was at the two-second rate, but to cause a decrease in recall and an increase in number of relearning trials with the four-second presentation. When results are given in terms of number of subjects showing reminiscence, these conclusions are confirmed.

7. The reminiscence effect following partial learning with the two-second presentation is most marked in the central portions of the list, and least at the ends. With the four-second rate, where little difference between the immediate

and two-minute scores is obtained, no differential effect upon the various portions of the list is indicated.

8. Evidence is presented against explanations of the results in terms of rehearsal, perseveration, fatigue, or motivation. Removal of inhibition explains the present results, but much more information concerning the nature of the inhibition is required.

The present results and those previously reported (**9**) do permit us to relate reminiscence to the factors causing the accumulation of difficulty in the central serial positions ('intra-serial inhibition'). Procedures which decrease this difficulty reduce reminiscence effects.

(Manuscript received October 21, 1937)

References

1. Ballard, P. B., Obliviscence and reminiscence, *Brit. J. Psychol. Monog. Supp.*, 1913, **1** (No. 2), pp. vi + 82.
2. Curtis, J. N., Two studies in memorizing by slow and by rapid repetition. II. The relative amounts of fatigue involved in memorizing by slow and by rapid repetition. *Psychol. Monog.*, 1916, **22** (No. 96), pp. 155–190.
3. Dashiell, J. F., *Fundamentals of objective psychology*, New York: Houghton, Mifflin, 1928, pp. xviii + 588.
4. Ebbinghaus, H., *Grundzüge der Psychologie*, Leipzig, Veit, 1902.
5. Ephrussi, P., Experimentelle Beiträge zur Lehre vom Gedächtnis, *Zsch. f. Psychol.*, 1904, **37**, 56–103; 161–234.
6. Ernst, J. L., F. E. Smith, L. R. Moessner, E. S. Rudisill, and M. J. Atwater, I. Further data for an associative limen, *Amer. J. Psychol.*, 1924, **35**, 255–261.
7. Gamble, E. A. McC., Two studies in memorizing by slow and by rapid repetition. I. Rate of repetition and tenacity of impression, *Psychol. Monog.*, 1916, **22** (No. 96), 101–151.
8. Guthrie, E. R., *The psychology of learning*, New York: Harper, 1935, pp. xviii + 258.
9. Hovland, C. I., Experimental studies in rote-learning theory. I. Reminiscence following learning by massed and by distributed practice, *J. Exper. Psychol.*, 1938, **22**, 201–224.
10. ——, 'Reminiscence' and distribution of practice in serial and paired-associate learning, *Psychol. Bull.*, 1937, **34**, 530–531.
11. ——, Experimental studies in rote-learning theory. III. Distribution of practice with varying speeds of syllable presentation. (In prep.)
12. ——, Experimental studies in rote-learning theory. IV. Reminiscence effects in serial and in paired-associate learning. (In prep.)
13. ——, Experimental studies in rote-learning theory. VII. Distribution of practice with varying lengths of lists. (In prep.)
14. Hull, C. L., The influence of caffeine and other factors on certain phenomena of rote learning, *J. Gener. Psychol.*, 1935, **13**, 249–274.

15. HULL, C. L., R. T. ROSS, D. T. PERKINS, AND C. I. HOVLAND, A mathematico-deductive theory of rote learning—a study in methodology. (In prep.)
16. MEUMANN, E., *The psychology of learning* (Tr. J. W. Baird, from 3rd Ger. ed.), New York: Appleton, 1913.
17. MÜLLER, G. E. AND A. PILZECKER, Experimentelle Beiträge zur Lehre vom Gedächtniss, *Zsch. f. Psychol. Erganz.*, 1900, 1, pp. xiv + 300.
18. OGDEN, R. M., Untersuchungen über den Einfluss der Geschwindigkeit des lauten Lesens auf das Erlernen und Behalten von sinnlosen und sinnvollen Stoffen, *Arch. f. d. ges. Psychol.*, 1904, 2, 93–189.
19. WARD, L. B., Retention over short intervals of time, Ph.D. dissertation, Yale University, 1934 (To appear in *Psychol. Monog.*).

THE EFFECT OF ELECTRIC SHOCK FOR RIGHT RESPONSES ON MAZE LEARNING IN HUMAN SUBJECTS

BY HERBERT GURNEE

Western Reserve University

The question of the effect of electric shock for right responses in learning situations has some importance for theories of learning, particularly for that theory known as the law of effect. But the experimental answers to the question have been on the whole somewhat uncertain. Tolman, Hall and Bretnall,[1] in a study of maze learning by human subjects, report that groups shocked for right responses did appreciably better than groups shocked for wrong responses. Muenzinger[2] in a comparable experiment failed to get confirmatory results, although in a previous study of white rats[3] he observed that shocking the animal in right alleys facilitated the elimination of errors.

It may be that the different findings in these two studies of human learning were a function of different degrees of shock. It is conceivable that a light shock with little annoying effect might act as a sensory reinforcement to facilitate the acquisition of right responses, whereas a heavy shock might arouse avoiding tendencies so strong as to interfere with this acquisition. In an effort to discover whether this was so, the present experiment was carried out. Briefly, our problem was to investigate, in maze learning situations with human subjects, the effect of two significantly different intensities of shock for right responses. For purposes of comparison,

[1] Tolman, E. C., Hall, C. S., and Bretnall, E. P. A disproof of the law of effect and a substitution of the laws of emphasis, motivation and disruption. *J. Exper. Psychol.*, 1932, 15, 601–614.

[2] Muenzinger, K. F. Motivation in learning. II. The function of electric shock for right and wrong response in human subjects. *J. Exper. Psychol.*, 1934, 17, 439–448.

[3] *Idem.* Motivation in learning. I. Electric shock for correct response in the visual discrimination habit. *J. Comp. Psychol.*, 1934, 17, 267–277.

observations were also made of the effect of giving the two intensities of shock for wrong responses.

Apparatus

The maze was of the bolthead type. Its main feature was a vertical panel with parallel rows of brass bolts equidistance apart. The panel was a sheet of heavy grey cardboard, 71 cm long and 56 cm high, fastened to a wooden frame 20 cm deep. The bolts were 3/4" × 8 round head brass machine screws, set 2½ cm apart each way in 21 horizontal and 27 vertical rows. Copper washers were placed under the heads of the bolts. On the top of the maze near the front edge were two flash-light lamps 20 cm apart. One lamp was painted red, the other was unaltered. An irregular pattern of 28 bolts in a contiguous series was wired on the back of the panel and placed in circuit with a pointer and the white light. This constituted the correct pathway. The bolt at the bottom of this pathway was labelled S (start), the one at the top was labelled G (goal). All other bolts were wired in circuit with the pointer and the red lamp; they constituted errors.

The pointer was a three inch copper wire nail inserted part way into a wooden handle, from the other end of which an insulated wire ran to two dry cells. A piece of sheet brass around the wooden handle served as one electrode from the secondary of a variable inductorium. A piece of brass tubing held in the subject's free hand served as the other electrode from the secondary.

The inductorium was the DuBois-Reymond model sold by Stoelting. The primary was wired with two dry cells and a two-way switch. By means of the switch the coil could be thrown into circuit with either the correct or the incorrect bolts. The interrupter of the coil was used and the points were set at a relatively high frequency. Thus a practically continuous shock was received as long as a bolt in the primary circuit was contacted.

The maze was placed on a small table, with the panel vertical and flush with the edge of the table. The subject sat directly in front a comfortable arm's length away.

Procedure

There were five groups of subjects, each group comprising 20 or 21 male undergraduates. One, the control group, received no shock at any time. The other groups received shock beginning on the fifth trial. Two of these received light shock, one whenever a correct bolt was contacted, the other whenever a wrong bolt was contacted. The remaining two groups received moderate shock, one for correct contacts, the other for wrong contacts. By treating all subjects alike on the first four trials and not introducing shock until the fifth, it seemed possible to get a measure of the comparability of the groups. The decision whether a subject would be given shock, and if so in what manner, was determined by lot after the fourth trial. This was to produce an unselected sampling and to equalize the factor of expectancy during the first four trials.

The subject was told that his problem was to go from the bolthead marked S to the bolthead marked G without hitting any red lights. There was, he was informed, only one correct path and it was indicated by the white light. If he contacted a bolthead giving a red light an error was scored against him and he was to go back to the white light just left and proceed in another direction. He could go up, down, right or left but not diagonally, and he could not skip any bolts. He was further told that his trials would be timed but that this was unimportant; his chief concern should be to avoid errors and he should consider time only to the extent of not loitering.

At each point of the maze except the next to the last there were, obviously, four possible choices. One of these meant a reversal and reversals were not counted; rather the subject was informed when, as rarely happened, he proceeded backward. So the practical choices were reduced to three, one of which was right.

The two positions of the secondary coil were determined beforehand from the responses of a small disinterested group and were not changed thereafter. The settings were established at points which seemed to come nearest to producing agreement that the effects were, respectively, mildly annoying and moderately annoying. The verbal reports of the subjects later gave confirmation to these settings. In these reports subjects were asked to rate the shock on a scale from extremely pleasant to extremely annoying. They were also asked to indicate the effect of the shock upon their alertness, attentiveness and their effort to learn.

The trials were continued to two consecutive errorless runs, with the following exceptions. Subjects in the control and light shock group were not carried beyond 20 trials, subjects in the moderate shock groups were not carried beyond 12 trials. Apparently, all might just as well have been stopped after 12 trials, for as far as our criterion (comparative errors) was concerned, nothing seemed to be gained by the additional trials, where given. All trials were performed in one sitting, which required from 15 to 30 minutes.

Results and Discussion

The quantitative data appear in the tables. The averages and standard deviations for errors per trial are given in Table I; the critical ratios for errors and for time in seconds per

TABLE I

Errors

Trials		1	2	3	4	5	6	7	8	9	10	11	12
N.S.	Av.	21.43	9.95	7.14	5.76	5.14	4.71	3.62	2.95	1.86	1.71	1.33	1.19
	S.D.	13.30	3.87	2.50	2.25	2.90	2.74	2.91	2.57	1.62	2.13	1.58	1.68
L.S.R.	Av.	19.60	10.10	8.75	6.80	5.65	4.50	3.95	2.75	2.70	2 10	1.30	1.45
	S.D.	9.46	6.90	4.84	2.88	2.64	2.60	2.92	2.06	2.20	2.14	1.57	1.80
M.S.R.	Av.	20.00	9.35	7.10	6.25	9.15	5.25	4.05	2.85	2.10	1.95	1.50	1.22
	S.D.	13.51	4.69	3.10	3.16	10.36	4.27	3.97	1.69	1.61	1.72	1.56	1.16
L.S.W.	Av.	19.48	8.95	7.71	6.52	5.71	4.38	3.19	2.33	2.09	2.09	1.38	1.09
	S.D.	8.43	2.79	4.47	3.38	3.64	3.82	2.54	2.24	2.39	2.20	1.63	1.51
M.S.W.	Av.	20.71	10.95	6.86	5.29	5.14	3.14	2.95	2.38	1.90	1.33	0.86	0.74
	S.D.	12.86	6.58	3.58	3.01	2.84	1.87	2.19	1.80	1.48	1.86	1.56	0.95

trial are given in Table II. N.S. represents the no shock or control group. L.S. stands for light shock and M.S. for moderate shock; R and W refer to the responses, right or wrong, for which the shock was given.

TABLE II

CRITICAL RATIOS OF ERROR AND TIME DIFFERENCES

Trials		1	2	3	4	5	6	7	8	9	10	11	12
L.S.R.	E	+0.49	−0.08	−1.30	−1.25	−0.57	+0.25	−0.38	+0.24	−0.41	−0.57	+0.06	−0.46
	T	+0.56	−0.25	−1.27	−0.30	−0.52	+1.46	+1.27	+1.81	+0.09	+1.21	+1.24	+1.25
M.S.R.	E	+0.33	+0.43	+0.04	−0.56	−1.62	−0.47	−0.38	+0.14	−0.39	−0.39	−0.34	−0.21
	T	+0.38	−0.37	−0.10	+0.27	−1.61	+1.32	+1.44	+1.16	+0.96	+1.65	+1.34	+2.31
L.S.W.	E	+0.55	+0.93	−0.49	−0.84	−0.55	+0.31	+0.57	+0.72	−0.35	−0.55	−0.10	+0.19
	T	+0.69	+0.81	+0.01	+0.15	−1.34	+0.20	+1.14	+0.69	+0.31	−0.11	+0.68	+0.46
M.S.W.	E	+0.17	−0.59	+0.29	+0.56	0.00	+2.12	+0.83	+0.80	−0.08	+0.59	+0.96	+1.05
	T	−0.05	−1.00	−0.78	−0.28	−2.41	−0.25	−0.01	+0.24	−0.71	−0.10	+0.08	+0.36

The critical ratio in each instance is the difference between the two means for the given trial, divided by the standard error of that difference. Where the difference is in favor of the experimental group, that is, where the experimental group has the fewer errors or the shorter time, the ratio is given a plus sign; where the reverse is true, it is given a minus sign. It will be seen that the ratios are rarely large enough to be of statistical significance. In the shock trials, 5 to 12, 28 of the 32 critical ratios for error differences are below one, which, in a normal distribution, would represent a probability of .841. Only one of the error ratios meets Fisher's test of significance (probability of .05 that the difference could arise in a chance situation). The critical ratios for time tend to be somewhat larger, although not significantly so; for trials 5 to 12, one-half are below one, and only 2 meet Fisher's test of significance. Thus the effect of the shock is seen to be, on the whole, rather slight; and, at least as far as errors are concerned, it does not appear to be noticeably consistent.

One gross method of uncovering a possible trend is to summate the errors of trials 5 to 12 for each of the five groups. When this is done, the results are as follows: control group 22.51; light shock right group, 24.40; moderate shock right group, 28.07; light shock wrong group, 22.26; moderate shock wrong group, 18.44. These sums would seem to indicate that shock decreases errors when given for wrong responses but increases errors when given for right responses, increasingly

with greater intensity. This is what common sense, as well as the 1913 statement of the law of effect, would lead one to expect. But conclusions based on mere summation are open to error on at least two grounds. First, such totals weight all errors alike, regardless of where they appear, when errors occurring early in the learning series are obviously less important than those occurring late. Second, such comparisons assume that the several groups are all equal in ability, when the chances are inconsiderable that such small random samples would be equal; inspection of the data for trials 2 to 4 shows in fact that the groups are not equal.

A sounder and more discriminating means of comparison is available, namely, the comparison of relative probabilities. Thus, by determining both before and after the introduction of shock, the probability that a certain experimental group will have fewer errors than the control group, we obtain a measure of the effect of the particular experimental condition. Such probabilities are obtainable by the simple expedient of converting the critical ratios into their corresponding proportions, through reference to tables on the normal curve. The assumption of a normal distribution doubtless introduces some error, but not a serious one.

Table III presents the proportions for the four experimental groups. Each proportion is to be interpreted as the probability that the particular experimental group will have

TABLE III

PROBABILITY THAT EXPERIMENTAL GROUP WILL EXCEL CONTROL GROUP

Trials	3–4	5	6–7	8–9	10–12
Errors					
L.S.R.	.102	.285	.476	.468	.377
M.S.R.	.402	.053	.336	.452	.377
L.S.W.	.257	.292	.669	.564	.409
M.S.W.	.663	.500	.889	.629	.802
Time					
L.S.R.	.243	.302	.912	.750	.891
M.S.R.	.534	.054	.916	.854	.950
L.S.W.	.531	.091	.726	.688	.628
M.S.W.	.304	.008	.450	.417	.544

fewer errors, or shorter time, than the control group, in the trial or trials named. Trials 1 and 2 were left out because of the large factor of chance which they involved. Pairs of trials were combined in order to increase reliability. An exception was made of trial 5.

There were two reasons for keeping trial 5 separate. In the first place, it was evident from the data that the introduction of shock caused a disruption of performance in certain situations; separate treatment therefore gave a measure of this effect, and at the same time it prevented a probable warping of the general trend. In the second place, the results from trial 5 could not be taken as indicative of the strengthening or weakening effect of the shock so far as the establishing of associative connections was concerned. Whether the shock strengthened or weakened associative connections could only appear when the situation presented itself again, namely, in the next trial.

In the comparisons that follow it will be assumed that the proportions for trials 3–4, Table III, indicate approximately the relative abilities of the groups. The values are not reliable enough, especially this early in the learning period, to be accepted strictly at their face value; nevertheless, they offer the best basis of comparison available and are preferable to any assumption of group equality. It appears, from these figures, that the light shock right (L.S.R.) and the light shock wrong (L.S.W.) groups, the former especially, were definitely inferior in ability to the control group (.50 would represent equality), that the moderate shock right group (M.S.R.) was somewhat inferior, and the moderate shock wrong group (M.S.W.) was somewhat superior to the control group.

With the introduction of faradic stimulation, the number of errors became subject to four new possible factors. The shock might strengthen associative formations, that is, the establishing of associative connections; it might weaken associative formations; it might facilitate associative functioning, that is, the functioning of associations developed by previous trials; or it might inhibit or disrupt associative functioning. The analysis of our data in terms of these four

factors is at some points difficult, at other points impossible. A measure of the effect upon associative functioning is presented by the error proportions for trial 5. An increase over the proportions for trials 3–4 may be taken, tentatively, as evidence of facilitation, a decrease as evidence of disruption or inhibition, in amount proportional to the amount of the difference. It then appears that the facilitating factor predominated in the light shock situation and the disrupting factor in the moderate shock situations. Moreover, the predominance, whether of facilitation or disruption, was evidently greater in the shock right than in the shock wrong situations. This last fact is perhaps explained by the greater number of shocked responses in the former situations: for there were consequently many more chances for facilitation or disruption to operate.

After trial 5, the effect of shock upon associative formation enters the proportions, and interpretation becomes difficult. All the error proportions show a marked rise in trials 6–7, and they remain well above the level of trial 5 for the rest of the period. Presumably most of this rise is ascribable to the reinforcement of associative formation, but one can not be sure. Doubtless, because of adaptation, some of the rise is a result of lessened disruption; and it is possible that some is a result of increased facilitation of associative functioning, although adaptation would tend to lessen this also. If these two factors adapted out equally, we could take the level of trial 5 from which to measure the effect on associative formation. But we do not know that they did so adapt; it is rather likely that disruption decreased the more quickly of the two. At least we are able to say, tentatively, that any significant gain in proportion beyond the value for trials 3–4 may be ascribed to a dominance of reinforcing factors, however related, and that any significant loss may be ascribed to a dominance of disrupting factors.

With these interpretative considerations in mind, we may turn to an examination of some of the specific results. It is clear, from the data on errors in Table III, that light shock for right responses was considerably more reinforcing than dis-

rupting, for the probability is increased by .374 in the peak trials, 6–7. The average for trials 6 to 12 is .431, or .329 better than the figure for trials 3–4. If the proportion for trial 5 is averaged in, the net gain becomes .311 instead of .329.

Moderate shock for right responses gave a different result. The disrupting factors evidently dominated, except in trials 8–9 (actually 8), where they seem to have been slightly overbalanced by the reinforcing factors. The average proportion for trials 6–12 is .387, which represents a slight net loss, too slight to be of significance. With trial 5 included, the net loss is .057.

The effect of the light shock for wrong responses was evidently similar to its effect for right responses. The reinforcement was relatively greater in trials 6–7 but relatively less in trials 10–12, than for the latter group. The average for trials 6–12 is .528, a net gain of .271 over trials 3–4. With trial 5 included, the net gain is .241. These figures are somewhat below the corresponding values for the light shock right group, and they point to the latter condition as the slightly more effective of the two. This is in line with the results of Tolman, Hall and Bretnall.

A greater difference in effects appears when we compare the two moderate shock groups. Whereas moderate shock for right responses tended to hinder the elimination of errors, moderate shock for wrong responses tended to do the opposite. There was a singular drop on trials 8–9 (actually 9); otherwise all proportions were above the level of trials 3–4. The average for trials 6 to 12 is .777, which is .114 above trials 3–4. With trial 5, the net gain is reduced to .080. These figures are below the corresponding values for the light shock groups, and indicate that light shock for either right or wrong responses was more effective than moderate shock for wrong responses.

Vaughn and Diserens,[4] in a study of the effect of three degrees of shock for errors on maze learning by human subjects, have reported that light shock was more effective than either moderate or heavy shock in the elimination of errors. Our results are in accord with their's on this point.

[4] Vaughn, J., and Diserens, C. M. The relative effects of various intensities of punishment on learning and efficiency. *J. Compar. Psychol.*, 1930, **10**, 55–66.

Because of the subjects' instructions, the temporal differences among the groups are of only slight experimental importance. By reference to Table III, it will be seen that the shock at first had a markedly retarding effect on three of the four groups. This was particularly true of the moderate shock groups. Thereafter all groups show facilitation, particularly the two shock right groups, who, in terms of relative proportions, gain more than twice as much as the corresponding shock wrong groups. It is also apparent that the light shock right group makes the largest relative gain of all.

The time per trial was necessarily a function of four variables: (1) the number of boltheads contacted, (2) the durations of contacts, (3) the durations of the intervals between contacts and (4) the speed of movement. It is impossible to designate the relative effects of these in quantitative terms. However, both behavioral observations and logical deductions enable one to say that the temporal superiority of the shock right groups over the shock wrong groups was primarily the result of a larger number of shortened contacts. The durations of the intervals between contacts did not appear to be decreased by the shock, but rather the contrary; the marked retardations on the fifth trial appeared to be almost wholly a result of delayed intervals. Shock increased the speed of withdrawal, naturally, and thus was a second aspect in which the shock right groups had an advantage. The relative number of boltheads contacted was not an important factor, as can be seen by an examination of the results for the moderate shock right group. This group was highest in errors but fastest in time; while the moderate shock wrong group was lowest in errors and slowest in time.

In their verbal reports, the subjects were almost unanimous in reporting that the shock increased their alertness and attentiveness, and their effort to learn. The observations of behavior tended to confirm these reports. Subjects often manifested a noticeable increase in muscular tonus after the shock trials began. They usually sat more erect and appeared more intent. We may suppose that this increased alertness and attentiveness was responsible for much of the reinforcing

effect obtained in some of the experimental situations. Added to this was doubtless a sensory reinforcement; that is, the shock served as an additional and more impressive sensory cue, or as what Tolman, Hall and Bretnall have called an emphasizer.

It may be questioned why, in the presence of these specific and general reinforcing factors, there was not a greater improvement in results. The answers are two. In the first place there were, as has been indicated, disrupting factors to oppose the reinforcing factors, and it is reasonable to suppose that these were nearly always present to some extent, even in the situations of greatest improvement. In the second place, as Muenzinger has suggested, the subjects were very likely so highly motivated already as to leave little chance for improvement of performance.

One further point requires mention. While most of our subjects agreed in designating the one shock as mildly annoying and the other as moderately annoying, there were some who departed from this. One subject found the moderate shock so unbearable that he quit the experiment during the seventh trial. At the other extreme were a few subjects who reported the light shock as actually pleasant. As a matter of fact, one does not have to go to the laboratory to discover that some persons get an agreeable thrill out of at least mild faradic stimulation. All of this raises an important question, namely, how can the punishing value of a shock, or of any situation of the kind, be defined? Obviously, there is need for some objective means of determination; the mere quantifying of the stimulus is not enough. The only available device we have for human subjects is the rating scale, and it is only an expedient.

Summary

Four experimental groups and one control group of human subjects were run through a bolthead maze. The experimental groups received light or moderate shock, for right or wrong responses, beginning with the fifth trial. In terms of the major criterion, a gain or loss in the probability of fewer

errors than the control group, the following results appeared: Light shock for either right or wrong responses and moderate shock for wrong responses were better than no shock, and no shock was better than moderate shock on right responses. The most effective condition was light shock on right responses and the least effective was moderate shock on right responses. Light shock on wrong responses was more effective than moderate shock on wrong responses. The results were discussed in terms of reinforcing and disrupting factors. The differences were rarely large enough to be statistically significant.

(Manuscript received December 10, 1937)

A NEW METHOD FOR THE UNINTERRUPTED REGISTERING OF BLOOD PRESSURE AS A PSYCHO-PHYSIOLOGICAL RESEARCH-TECHNIQUE FOR THE STUDY OF PSYCHIC STIMULI ON THE BLOOD PRESSURE *

BY DR. BERTHOLD STOKVIS

The need of the possession of a useful, simple method of uninterrupted, automatic measuring and registration of blood pressure in man is felt by every research-worker, whose sphere of action concerns blood pressure; according to the usual methods of measuring, only one point of the curve is found as the value of blood pressure, which gives an insufficient impression of the general condition of the same in the examined person.

The hitherto described methods, which lead to this purpose, can be classified in two groups. The first group concerns the uninterrupted measuring of blood pressure in a direct way. To this group belongs the boulittograph, for the description of which I refer to Giroux and Boulitte.[1] The second group includes the methods of continuous measuring of the pressure in an indirect way. This group breaks up in:

(*a*) methods, in which compression is used by means of a cuff;
(*b*) methods, by way of a plethysmograph and
(*c*) other methods.

Under group (*a*) is mentioned the method by De Vries Reilingh,[2] a complicated test, lately used by Storm and Bor; [3]

* From the psycho-physical laboratory of the psychiatric clinic of the state-university at Leiden (Holland), Superintendant: Prof. Dr. E. A. D. E. Carp.

[1] Giroux, René et G. Boulitte: Etude du système circulatoire et du fonctionnement cardiaque au moyen de l'enregistrement de la pression artérielle; nouvelle méthode d'exploration, *Presse méd.*, 1933, **2**, 1586–1588.

[2] Vries Reilingh, D., De: *Techniek en kliniek der bloeddrukmeting*, J. B. Wolters Uitg. Mij., Groningen, den Haag, 1915.

[3] Storm, C. J. and H. A. Bor: Evipan-natriumvarcose in de mond- en kaakchirurgie, *Ned. T. v. G.*, 1935, **79**, 2627–2641.

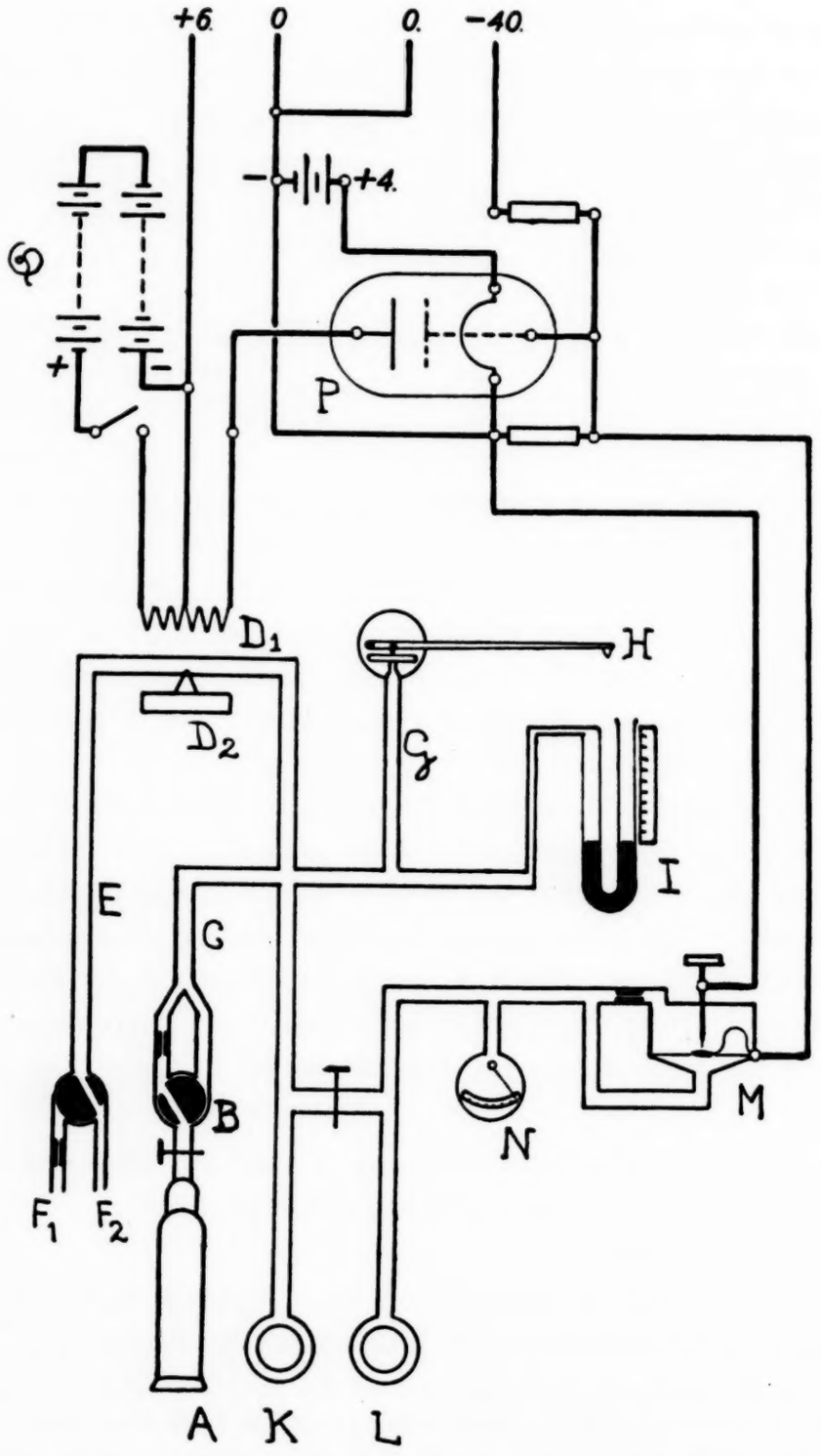

FIG. 1. Scheme of the apparatus (trial arrangement).—On the scheme is given: (below 2nd from the left) the pressure cylinder *A*, with a three-way-cock *B* for change of the inflow-path *C*. This cylinder is connected with: (1) the electromagnetic switch *D1* and *D2* of the outflow-path *E* (left middle), which ends in the interchangeable outflow-path *F1* and *F2* (left below); (2) the manometer *G* with registration needle *H* (middle); (3) the mercury manometer *I* for control (right from the middle); (4) the

besides Uskoff-Bickel's method,[4] wherein the Uskoff's sphygmotonograph is used. A long time ago the last one was replaced by Plesch's tonoscillograph. In this method one cuff is used. In the oscillometric method, as described by Lange,[5] which just like the method to be described here, is based on Kolls's [6] principle, described already in 1920, two cuffs must be used. To this we come back in detail later on. To group (*b*) belong the Mosso's fingerplethysmograph, the Lehmann's armplethysmograph and such-like, which are now of historical importance only (see Lehmann [7]). Group (*c*) includes the continuous measuring in an electrocardiographic way, for instance by means of the Einthoven's stringelectrotype, lately Trömner [8] has pointed out the importance of this method. The method as described by Golla and Antonovitch, which registers the pressure in the arteria dorsalis pedis, also belongs to this group. With the complicated method, as described by Thompson,[9] which consists of a modified

[4] Bickel, Heinrich: *Die wechselseitigen Beziekungen zwischen psychischem Geschehen und Blutkreislauf mit besonderer Rücksicht der Psychosen*, Veit and Comp., Leipzig, 1916, p. 14–21.

[5] Lange, K.: Die fortlaufende selbsttätige Messung und Registrierung des menschlichen Blutdruckes, *Dtsche med. Wochenschr.*, 1932, no. 11; see also Von Bergmann: *Funkt. Pathol.*, J. Springer, Berlin, 1932, p. 249 and 261.

[6] Kolls, A. C.: *J. Pharmacol. a. Exp. Therap.*, 1920, **15**, 433.

[7] Lehmann, Alfr.: *Die Hauptgesetze des menschlichen Gefühlslebens*, O. R. Reisland, Leipzig, 1892.

[8] Trömner, K.: Blutdruckregistrierung mit dem Elektrokardiographen, *Klin. Wochenschr.*, 1927, no. 42. Ref. *Dtsche med. Wochenschr.*, 1927, **53**, 1919.

[9] Thompson, J. H.: *Lancet*, 1928, **215**, 284.

---

proximal rubber-bag *K* (volume for the pressure to be measured) (3rd from left below). —Beside the distal airbag *L* is drawn (4th from left below), which is connected with: (1) the oscillation contact *M* (quite right); (2) a controlling manometer *N* (2nd from right).—The upper part of the scheme represents the amplifier. When through the oscillation contact *M* oscillations are caught, contact is made, through which grid and plate of the amplifier-lamp *P* are connected and the anode current of the lamp closes the outflow-path *E* at *D1* and *D2* (left middle). When the contact is open, the grid receives a negative grid tension from a Philips's power supply unit, of which the indications +6, 0 and −40 represent the connections; the anode current of the lamp gets now 0. Left at the top an auxiliary battery *Q* is given in scheme, which just neutralizes the anode current of the lamp at a passage of the current in the electromagnetical switch, so that through this the action of the lap, consequently also of the oscillation contact, is reversed.

At this trial arrangement is used a permanent opened inflow-path *C* of the compressed gas and further only one oscillation contact *M*.

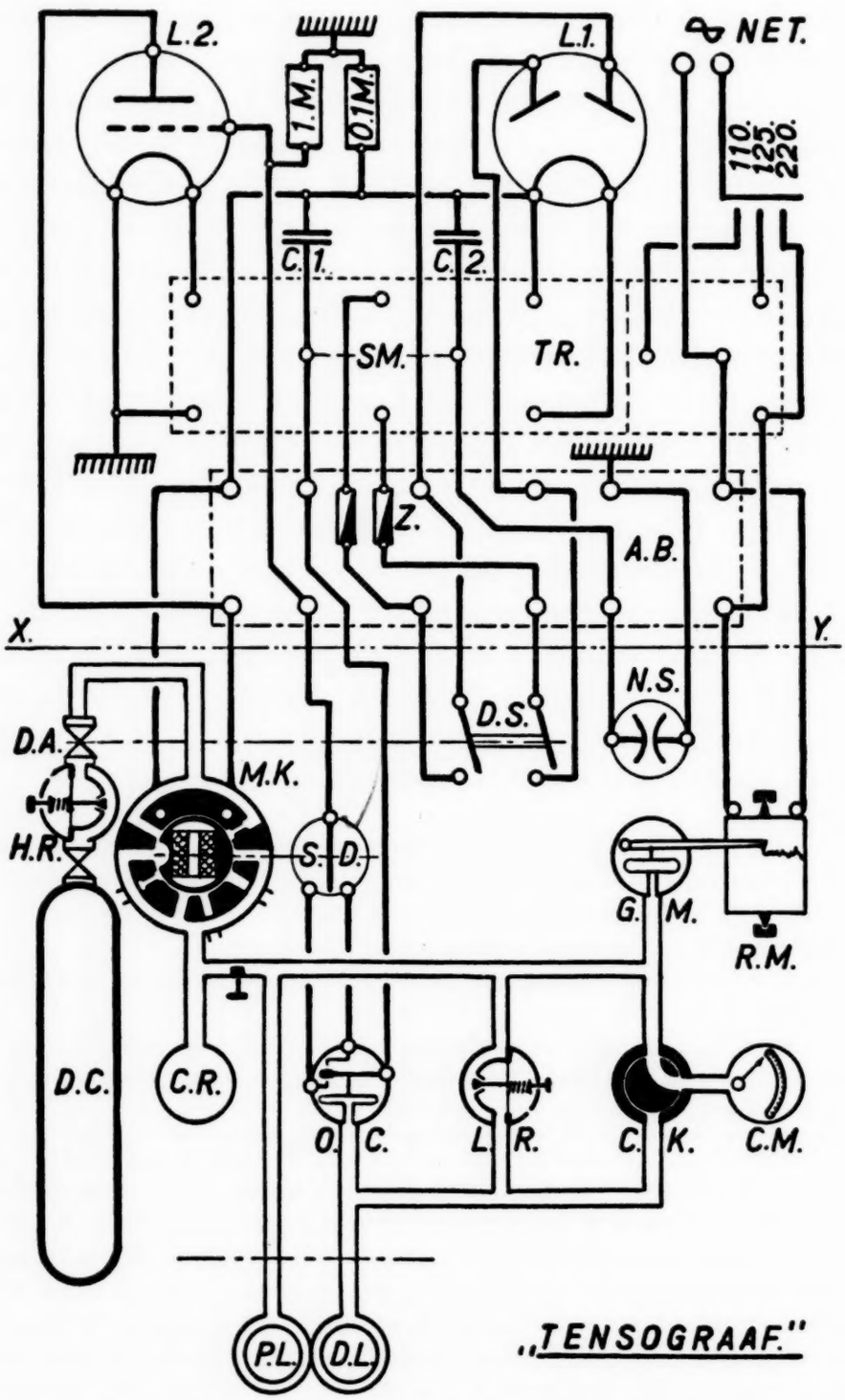

FIG. 2. Scheme of the apparatus (final arrangement).—Alphabetical order of the indications, used in the drawing. *A.B.:* Panel for the connections of the amplifier. *C1* and *C2:* Electrolytic condensers 8 μf 450 V. *C.K.:* Regulating cock, which makes it possible to verify the pressure and the auxiliary pressure. *C.M.:* Controlling meter. *C.R.:* Small compensation reservoir, which together with a small cock compensates the air impulses, which might possibly occur by the cock. *D.A.:* Handle to cut off the pressure, which is set on simultaneously with the double switch *D.S.* *D.C.:*

pressure-gauge and with which only oscillations in pressure can be observed, the height of pressure must be calculated separately. This instrument is of small importance for practice.

A useful method for uninterrupted registration of blood pressure has to meet the following criteria: (1) again and again the same pressure must be measured; (2) the artery may not be pinched off completely; (3) the patient may not be troubled too much by the continuous measuring; (4) it is desirable to verify the usual clinical values of pressure.

In the method to be described here, we have started—like Lange—from Gallivardin's principle, according to which two cuffs are desirable. The upper rubber-bag serves for pinching off; the lower one for catching off of the oscillations. The incipient effort to suffice with one bag failed, because at a pinching off above the value of the systolic pressure, the oscillations did not quite vanish. By means of a cock, moved electromagnetically, a pressure in the proximal rubber-bag is admitted, which ought to pinch off the artery more or less. This cock is put into action by a triode amplifier, the grid circuit of which is closed or cut off by a contact. This 'oscillation-contact' communicates with the distal rubber-bag,

Pressure cylinder, which contains 150 L. air. *D.L.:* Distal airbag. *D.S.:* Double switch, for protection of the rectifier. *G.M.:* Graving meter, which indicates 50–300 mm Hg. *H.R.:* High pressure reducer, in which about 1 atm. is admitted. *L1:* Double mercury vapour rectifier. *L2:* Amplifier valve. *L.R.:* Low pressure reducer, which gives the auxiliary pressure. *1 m.* and *0.1 m.:* Resistances of 1 and 0.1 megohm. *M.K.:* Magnetical cock (see text). *Net:* Connection for the a.c. network. *N.S.:* Neon stabilising lamp, which serves at the same time for signalling and illumination. *O.C.:* Oscillation contact (see text). *P.L.:* Proximal airbag, *R.M.:* Registering motor, a synchronous motor, which moves forward the registration paper at the uniform rate of 3 cM a minute. *S.D.:* Systolic-diastolic, switch, which is changed over together with the magnetical cock. *S.M.:* Choke, part of the amplifier. *Tr.:* Transformer, feeding circuit. *X.Y.:* Dividing-line between amplifier and other parts of the apparatus. *Z.:* Fuses 100 m.A. for protection of the rectifier valve and feeding circuit.

Explanation of the electrical part of this drawing. Above the dividing-line *X.Y.* is on the drawing the panel for the connections *A.B.* (that is encircled by a dotted line) of the compactly built amplifier. From left to right one finds the connections for the magnetical cock *M.K.* Beside it is the sparkless contact *O.C.;* then follow four connections *D.S.* for the double switch; then two for the neon stabilising lamp *N.S.*, which serves too for signalling and illumination. Finally a fixed tap of the 220 Volt net tension for the registering motor *R.M.*

where a low pressure of 20–50 mm Hg permanently prevails. Because of the pinching off of the artery, there appear no more active oscillations in the distal rubber-bag. In this way during the registration of the systolic pressure by way of switching off the contact, the inflow-path of a constant supply of compressed gas to the upper bag is periodically opened whilst at the same time the outflow-path of this cuff to the outer world is closed; in the same way the above mentioned inflow-path is closed during the registration of the diastolic pressure, the outflow-path is opened at the same time. During the registration of the systolic pressure just on the moment, when the systolic pressure-height, starting from a higher value of pressure, is reached, oscillations appear in the distal bag; these oscillations cause, by way of a switching off of the mentioned contact and the magnetical cock, a rise of the pressure in the proximal bag, because the inflow-path is periodically opened and the outflow-path is closed. Through the rise of the pressure, however, the active oscillations in the lower rubber-bag stay away; anyway they are not steep enough to let pass through the inflow-path more compressed gas than can escape in the intermediate periods through the outflow-path. Then the pressure does not rise any more, and the systolic worth is reached, which is reflected by the registrator, which communicates only with the upper bag. This also makes apparent the regularity of the curve, which, save to the sensitive oscillation-contact and the magnetical cock, is owed also to the buffer-working of a very small compensation-reservoir, which settles the diminution and rise of the pressure each time with an impulse that is measured.

It would take us too far to talk about the various very diverging criteria of diastolic blood pressure, as are given by Cottet,[10] Marey, Pons,[11] Giesen,[12, 13, 14] Pachon [15] and Gley,

[10] Cottet: La méthode sphygmomanométrique auscultatoire, *Presse méd.*, 1917, 8 Octobre, no. 56.

[11] Pons, R.: A propos du critère oscillométrique dans la mesure de la pression moyenne efficace. Rôle des facteurs: Temps, travail, énergie et ondée sanguine, *C. r. Soc. biol. Paris*, 1935, **118**, 299–301; 622–624.

[12] Giesen, J. Th.: Kan men den diastolischen bloeddruk bij den mensch bepalen

Gomez and Vaquez.[16, 17] We will understand here by 'diastolic blood pressure' that pressure, at which the steepness dP/dt of the oscillations, which appear in the lower bag, increases suddenly. On the moment of registration the artery is just pinched off during the diastole of the heart: will the same quantity of blood, that during the diastole could rush along continuously at a pressure in the cuff, which is a bit lower than the diastolic pressure, will still pass, then this must happen suddenly, therefore each time with an impulse; so the steepness dP/dt of the oscillations is much larger above the diastolic pressure than that of the oscillations under the same.—At every pressure in the proximal rubber-bag, that is lower then the systolic pressure, evidently oscillations appear in the distal bag, which get steeper up from zero, in proportion to the rising of the pressure in the proximal bag, but which get, as a rule, suddenly considerably steeper, as soon as the pressure in the upper bag has reached a certain height, which we call the diastolic pressure, as a research, specially made for that purpose, has taught. This research also brought to light, that there is no important correlation between seize and steepness of the oscillations.

With the registration of the diastolic pressure a second contact-installation is used, which is installed independently of the systolic one and which is also sensitive for pressure impulses insensible to changes of the pressure with small dP/dt. As is noticed above, a diminution of pressure must be caused—at the registration of the diastolic pressure—in the upper bag by means of the oscillations, which appear in

door den manchetdruk af te lezen bij den grootsten uitslag van oscillometer of oscillograaf enz?, *Ned. T. v. G.*, 1935, **79**, 860.

[13] Giesen, J. Th.: De grootste uitslag van den oscillometer bij bloeddrukbepaling, *Ned. T. v. G.*, 1935, **79**, 5202–5203.

[14] Giesen, J. Th.: De grootste uitslag van het oscillogram, *Ned. T. v. G.*, 1936, **80**, 1392.

[15] Pachon, V.: Sur la pression moyenne dynamique du sang ou pression efficace artérielle, *C. r. Soc. biol. Paris*, 1921, **84**, 868.

[16] Gley, P. et D. M. Gomez: La détermination des pressions moyenne et minima par la méthode oscillométrique, *Presse méd.*, 1931, no. 25, Février.

[17] Vaquez, H., Pierre Gley et D. M. Gomez: Etude théorique et pratique de la mesure de la pression moyenne par la méthode oscillométrique, *Presse méd.*, 1931, no. 71, 5 Sept.

the lower bag; when measuring the systolic pressure, the oscillations ought to achieve a rise of pressure. This diminution caused by the oscillations when registering the diastolic pressure, comes about, because of the outflow-path, which carries off the compressed gas out of the upper bag—the only bag, where the pressure is measured—which is opened periodically by the oscillations, while at the same time the inflow-path of the gas is blocked.

The consequence is, that the pressure sinks until the diastolic pressure is reached. Below this pressure the outflow-path would now be opened too shortly to let pass as much air as is let in through the inflow-path during the intermediate periods.

So the pressure, which is to be measured, cannot sink below the diastolic value. Thanks to a fixed regulation of the inflow-path and outflow-path of the gas, an equilibrium in the upper bag at a height of pressure, that fits the value of the diastolic pressure, is reached by the appearance of the oscillations in the lower one.

When, circumstantially, the diastolic pressure rises, the pressure in the proximal rubber-bag gets relatively too low; by this means the oscillations in the lower bag become more flat; therefore the little contact-spring is pressed during a shorter time against its antipode. The result is, that the outflow-path is kept open for a lesser time, while the inflow-path will be kept closed shorter. The result of this is, that the pressure in the proximal bag rises. When the diastolic pressure of the patient somehow sinks, the pressure in the upper bag will sink just as much; first this pressure is relatively too high, therefore the oscillations in the lower bag get steeper. The outflow-path is then opened longer and the inflow-path is closed longer: therefore the pressure in the upper bag sinks. When considering this principle closely, it is apparent, that the inflow-path and outflow-path of the gas both for the systolic and for the diastolic pressure are not equal. For the measuring of the diastolic pressure, the oscillations must open the outflow-path and close the inflow-path; during the short time, that the outflow-path is opened,

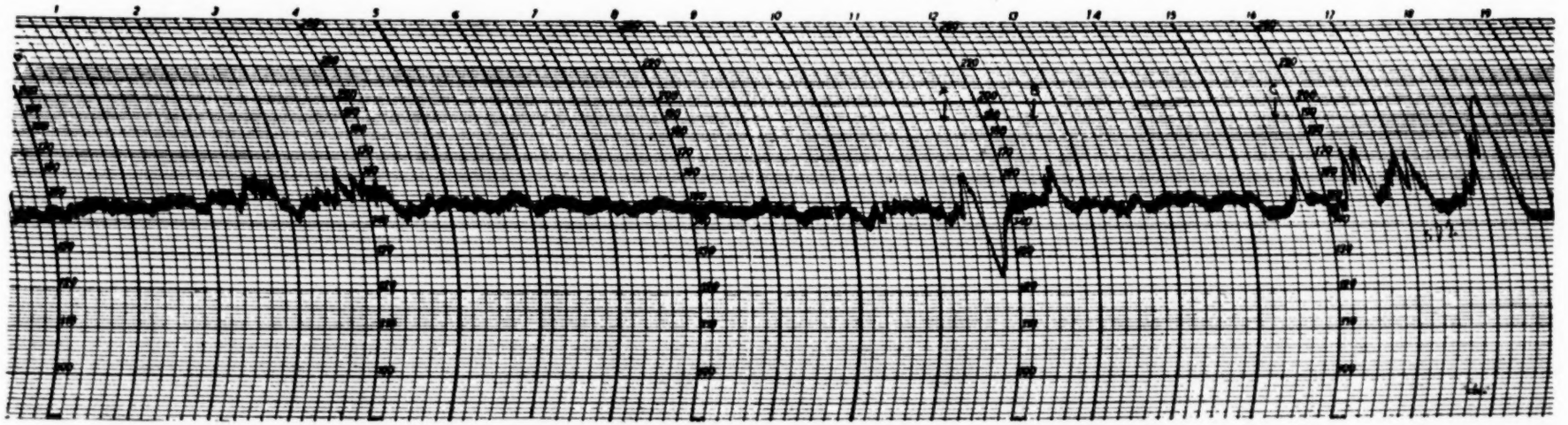

FIG. 3. The influence of some stimulations on the systolic blood pressure of a so-called tonolabile patient. At *A* the trigeminus-vagus-reflex is applied: first, the blood pressure rises a moment through the pain and the emotion, which are caused through the pressure, and sinks after that. At *B* some pain stimulations are applied; the blood pressure rises. At *C* an emotional conversation is held about the husband, with whom the patient is at variance; the blood pressure rises and shows oscillations.

as much gas must escape as during the long time, that the inflow-path is not blocked. So, when measuring the diastolic pressure, the inflow-path must be narrow, the outflow-path on the contrary must be wide. As for the systolic pressure: the inflow-path must be wide and the outflow-path must be narrow.

Perhaps the application of the apparatus described here, which every moment registers the same pressure, ought to contribute to the knowledge of the proportions of blood pressure in those cases, where a continuous measuring, respectively registering, must be considered desirable.

The method described above can be applied for the study of numerous psycho-physiological problems, amongst others for examining the influence of various psychic and sensorial stimuli on the blood pressure. We are giving below a synopsis of a research upon this subject. Twenty-one different stimuli were administered to ten normal persons and ten sufferers from essential hypertension and their influence on the systolic and diastolic pressure was registered. Although it is wrong to determine the average of changes in blood pressure with different persons without taking into account their basic blood pressure, we yet give below the average values for comparison. One should observe the change in blood pressure during the stage incrementi and that during the stage decrementi; we do not go further into the reaction-time, duration of the stage incrementi, acmes and decrementi. The results of the research are as on page 375.

Of all stimuli the affective ones have the greatest influence, from the affective ones especially those which are attended by a feeling of unpleasantness; *the greatest influence of all stimuli has the anxious expectation*, which conclusion coincides with that of Kronfeld, Müller and Reiner;[18] this is of importance for the way of originating of essential hypertension, of which it is assumed that psychic factors often have an influence. Furthermore it is evident that the diastolic blood pressure has reacted considerably less on the various stimuli than the systolic pressure.

[18] Kronfeld, Arthur, Adolf Müller und Rolf C. Reiner: Untersuchungen mit dem Autotonographen, *Z. f. d. ges. Neur. u. Psych.*, 1933, **145**, 62–98.

The patients with essential hypertension have generally reacted stronger than the normal persons; one may reduce

Kind of Stimulus	Changes in Blood Pressure in mm Hg *							
	Normal Persons				Sufferers from Essent. Hypertension			
	Systol.		Diastol.		Systol.		Diastol.	
	Stage Incr.	Stage Decr.	Stage Incr.	Stage Decr.	Stage Incr.	Stage Decr.	Stage Incr.	Stage Decr.
1. A march (Grenadier march)...	2.22	1.00	1.50	1.30	3.45	2.20	1.56	1.67
2. Seeing beautiful pictures.....	1.70	1.50	0.33	0.22	3.33	2.17	1.00	0.78
3. Smelling eau de cologne.....	1.44	0.56	1.00	1.11	2.00	2.18	1.30	1.00
4. A joke.....	3.22	2.56	1.70	1.10	3.40	3.10	2.00	2.00
5. Flattery.....	1.86	1.57	1.71	1.29	2.33	1.88	1.60	1.30
6. Pin-pricks.....	3.60	3.30	1.10	0.60	4.67	4.33	1.67	1.56
7. Pinching a fold of the skin with surg. tweezers.....	2.00	1.33	1.30	1.50	3.75	2.43	0.63	0.63
8. Pinching finger with pincers...	2.29	2.00	1.00	0.56	1.60	1.20	1.80	1.80
9. Smelling tinct. as. foetid.....	2.88	2.88	0.78	0.89	2.50	2.50	1.63	1.75
10. Questioning disagreeable facts (death parents).....	4.11	3.44	1.10	1.00	5.27	4.00	1.20	1.20
11. Announcing venapunction.....	2.90	2.10	2.14	1.86	6.00	4.67	1.44	1.67
12. Announcing electr. prickling...	?	?	x	x	4.00	4.00	1.67	1.67
13. Dropping an enamelled plate..	5.14	4.57	2.22	1.44	6.73	6.82	2.71	2.57
14. Clapping one's hands.....	1.25	1.75	0.63	0.38	2.00	1.67	—	—
15. Thought of something pleasant (rich uncle in America, obtaining a situation, pleasant event).....	3.00	2.40	1.60	1.60	4.55	4.09	1.70	1.90
16. Thought of something unpleasant (failing an exam., taxes-debt, awkward situation)...	0.78	0.78	2.00	1.80	7.10	6.80	1.10	1.50
17. Conversation on married life, engagement.....	2.83	2.17	2.63	2.63	8.72	8.72	1.13	1.38
18. Mental arithmetics.....	4.20	3.25	2.56	2.22	6.33	6.00	1.80	1.50
19. Inquiry into critic. power.....	2.75	2.25	2.00	2.33	5.00	5.00	3.00	2.00
20. Composing a sentence from three words.....	2.50	2.50	0.60	0.60	3.60	3.60	1.44	1.33
21. Change from rest to reading and writing.....	2.25	2.00	0.60	0.20	5.86	4.71	1.50	1.50

* This table is concerned only with the height of the changes, not with the sign.

From these data results the following.

1. Of the emotions of pleasantness (stim. 1–6) the telling of a joke has a great influence on the blood pressure.

2. Of the emotions of unpleasantness (stim. 6–11) the questioning re unpleasant facts has a great influence on the blood pressure; the same holds good for pain stimuli.

3. Of the emotive stimuli (11–18) the dropping of an enamelled plate on a concrete floor has great influence on the blood pressure.

4. Of the stimuli which require mental work, laborious calculating has the greatest influence.

this fact to the circumstance that the former are more emotional.

From the foregoing results that the reactions of the blood pressure on various stimuli allow certain conclusions, which contribute to the hypothesis of psychogenetic of the essential hypertension; we leave here out of consideration the many other ætiological moments such as the vascular (influence of the heart, vascular wall and of the perivascular tissue, of the blood fluid), the nervous factor (reflectory increase of the blood pressure, influence of the center of blood pressure), the humoral factor (influence of the suprarenal glands, of hypophysism of the kidneys, of the thyroid gland, of the gonads, of the glomus caroticum), the chemical factor, the mechanical factor and the connection with arteriosclerosis as well as many other endogene and exogene factors.

Summary

After a summary of literature about the uninterrupted measuring of blood pressure, a method is described for the uninterrupted automatic, bloodless registration of the systolic and diastolic blood pressure in man. From the reactions of the blood pressure on numerous psychic stimuli examined with this method a hypothesis is built up relating to the psychogenesis of essential hypertension.

(Manuscript received November 24, 1937)

A FURTHER INVESTIGATION OF THE ROLE OF EMPHASIS IN LEARNING

BY E. H. PORTER, JR.

University of Oregon

AND CALVIN S. HALL

Western Reserve University

It has been demonstrated by various investigators (**2**, **3**, **4**) that a stimulus, *e.g.*, buzzer or bell, facilitates learning more when it accompanies right responses than when it accompanies wrong responses. In these experiments, however, the differential amount of auditory stimulation received by the two groups was not adequately controlled. For, a subject that learned to make responses which caused a buzzer to sound would, with improvement, make more buzzer (right) reactions than a subject that learned to avoid responses which sounded the buzzer. Hence, it is possible that the greater effectiveness of emphasis for correct choices compared with emphasis for incorrect choices is caused by a greater amount of stimulation, and not by the circumstance that the emphasis accompanies correctness.[1] The present experiment was planned to equalize the amount of stimulation (emphasis) for the two groups.

Procedure

The learning task required the subject to make a series of twenty-four choices between two telegraph keys. The keys were seven inches apart and directly behind them was a dull black-board screen, 28″ × 22″. This screen served two purposes, it concealed the manipulations of the electrical circuits by the experimenter and it served as a support for two small radio panel lights, 6 to 8 volts. One light was fastened directly above each key.

Each subject in the experiment practiced pressing the keys until he had made two correct runs of twenty-four choices or until twenty trials had been completed. Both groups practiced the same series. For one group, however, the light above the correct key flashed on when the subject made *either a correct or an incorrect choice.* For the other group, the light flashed above the incorrect key when the subject made *either a*

[1] Gilbert (**1**) found, for example, that when a subject was given electric shocks his learning accelerated even though the shocks neither accompanied nor followed right or wrong responses.

correct or an incorrect choice. The former group will be referred to as the light-right group, the latter as the light-wrong group. The fact that a light always appeared no matter how the subject responded equalized the amount of light stimulation for the two groups.

Two groups (hereafter designated Group A and Group B) of thirty college students were used as subjects. Each member of both groups learned two different learning series. Group A learned in the first series to press the key which lighted the light directly above it and in the second series to avoid hitting this key. In contrast, Group B learned in the first series to press the key which did not light the light directly above it and in the second series to hit this key. The first series was identical for both groups. The same was true of the second series. This procedure permitted comparisons to be made between Group A as light-right versus Group B as light-wrong for the same learning task and between Group A as light-wrong and Group B as light-right for the same learning task. Any differences between the two groups due to inequality in learning ability rather than to the experimental variable should appear as a result of these comparisons.

The instructions read to each subject were as follows: "Before you are two telegraph keys, one to your left and the other to your right. The problems which you are to learn will consist of pressing in proper order these two keys. Each time one of the keys will be the correct one to press. Before you are to press the key that you think is the correct one a buzzer will be sounded. (A buzzer signal was employed to permit a shifting of circuits by the experimenter.) You are not to press until you hear the buzzer. Press only one key each time. Press the left key with the left hand and the right with the right hand.

"There are two series of left-right-presses that you are to learn. During one of these series you will try to press the key that will make the light just above that key go on. If, in this series, you should press an incorrect key, the light above the other key will flash on indicating that that key was the correct one. In other words, no matter which key you press the light will flash on above the correct key. In the other series which you are to learn the conditions are just reversed. Here the light will always flash on above the key which is incorrect.

"In each of the two problems there is a series of twenty-four presses. You will be told before starting whether you are to try to press the key which will turn on the light above it or whether you are to try to avoid pressing the key which turns on the light above it. Constant attention and effort should assure you of early success. Ask any questions that you want to now. Please do not talk during the experiment."

At the end of the practice period for the first series the subject was briefly instructed concerning the second series.

Results

The results are presented in the form of learning curves (Figs. 1 and 2) and in tables (Tables 1 and 2). It is apparent from an inspection of Fig. 1 that Group A (light-right) is superior on every trial to Group B (light-wrong). Although there is a difference in favor of Group A even on the first trial, which indicates that the subjects in Group A had an initial advantage over those in Group B, this difference becomes even

more striking as practice continues until about the fourteenth trial when there is a slight convergence in the learning curves again. This divergence with practice suggests that the

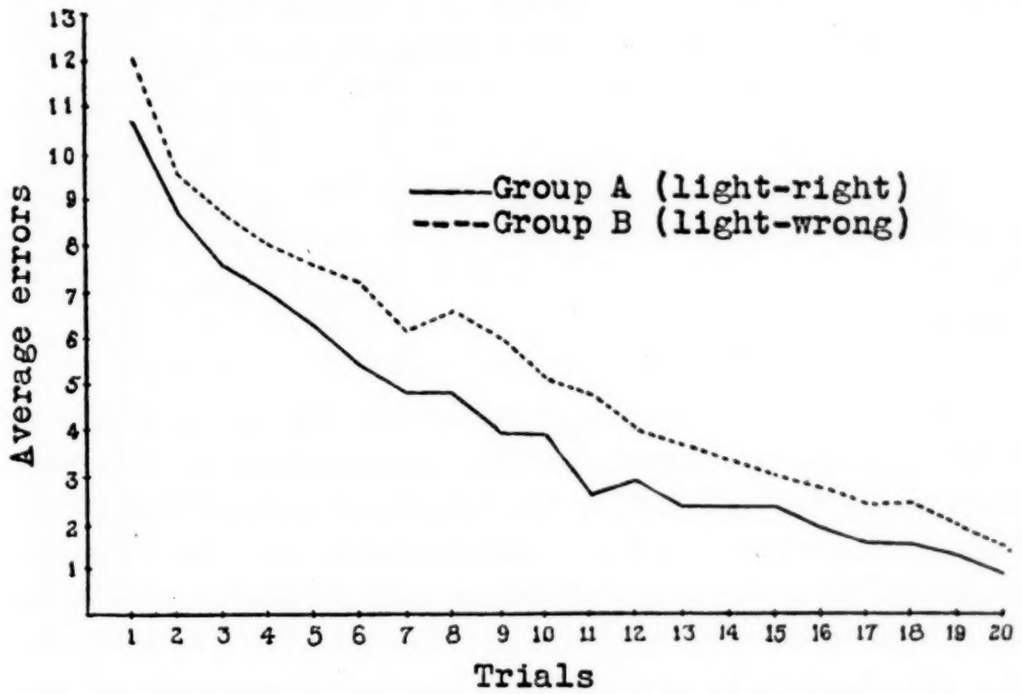

FIG. 1. Learning curves for Group A (light-right) and Group B (light-wrong) for the first learning task.

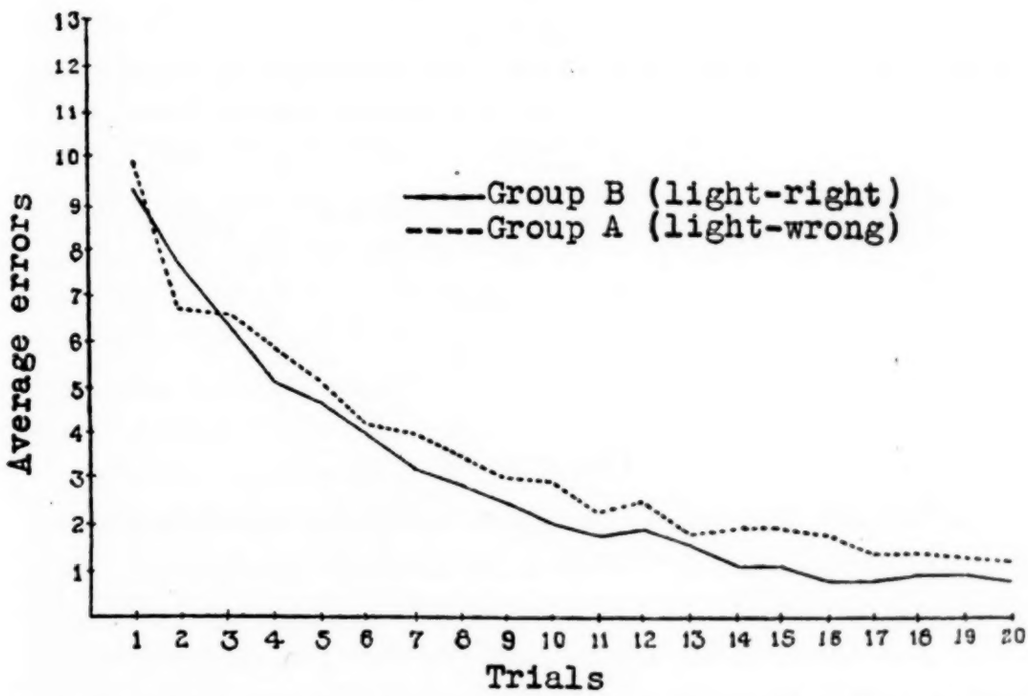

FIG. 2. Learning curves for Group A (light-wrong) and Group B (light-right) for the second learning task.

experimental variable was influencing the rate of improvement. The statistical analysis and comparison of the total error scores for the two groups are presented in Table 1.

TABLE 1

A Comparison of Average Total Error Scores for Group A (Light-right) and Group B (Light-wrong) for the First Learning Task

	n	Average Total Error Score	S.D.	Diff.	S.D. Diff.	Critical Ratio
Group A.....	30	82.6	43.06	−22.8	11.39	−2.00
Group B.....	30	105.4	45.22			

The difference, according to a rigorous statistical criterion, is not entirely significant. Before commenting on this first comparison, let us consider the results of the second series. The learning curves in Fig. 2 demonstrate that the formerly superior Group A, now the light-wrong group, is inferior in error score on every trial, except the second, to Group B, now the light-right group. The statistical analysis of the total error scores for the two groups is found in Table 2. Again, the difference is not statistically reliable.

TABLE 2

A Comparison of Average Total Error Scores for Group A (Light-wrong) and Group B (Light-right) for the Second Learning Task

	n	Average Total Error Score	S.D.	Diff.	S.D. Diff.	Critical Ratio
Group A.....	30	69.8	44.48	10.1	15.32	.66
Group B.....	30	59.7	71.25			

Discussion

Individual differences in learning scores are notoriously wide and consequently differences between groups are often over-shadowed by the variability within each group. Despite the lack of statistically certain differences, the writers believe there is sufficient evidence that a true difference between the two groups does exist and that this difference is due to the

nature of the experimentally controlled variable, light for correct responses vs light for wrong responses. This belief is substantiated by two facts. First, there is the superiority of the light-right groups over the light-wrong groups on every trial with but one exception. This is not the result expected if the differences were merely chance differences. Chance differences should yield reversals in superiority from trial to trial. Second, there is the fact that the two groups reversed their relative superiority when the experimental conditions were changed. Again, this would hardly occur as a consequence of a sampling error. If Group A were truly superior to Group B in learning ability, and if the experimental variables were playing no part in determining the scores, then Group A should continue to be superior to Group B on the second learning series. It is true that the difference on the second series is not as marked as on the first series, but the fact that it is in the same direction supports our belief that the reversal is due to the change in the experimental conditions.

Furthermore, the 'emphasizer' used in this experiment was quite mild, perhaps far more mild than emphasizers employed in natural situations. The use of more intense emphasizers, unless they led to emotional disruption, would doubtless yield a more striking disparity between emphasized wrong and emphasized right groups.

In view of the controls utilized in this experiment, namely, equalizing the amount of stimulation received by the light-right and light-wrong groups and requiring each group to practice under the two experimental conditions, the previously found result that emphasis for correct responses facilitates learning more than emphasis for incorrect responses is even more firmly established as a definite fact.

At the conclusion of his excellent monograph on reward and punishment, Waits remarks that "this study leaves open the question of 'what to do' if and when the learner makes a mistake" (**5**, p. 53). The present study contributes a practical suggestion as to 'what to do' as the result of an error. A wrong response should be followed up with emphasis upon the correct stimulus instead of calling attention to the incorrect stimulus.

Summary

Two groups of subjects (30 in each group) practiced a simple learning task consisting of making a series of choices between a pair of telegraph keys. For one group, either a correct or incorrect response was followed by flashing a light above the *correct* key. For the other group, either a correct or incorrect response was followed by flashing a light above the *incorrect* key. The members of each group acted as subjects under both experimental conditions. In each case, flashing a light over the correct key facilitated learning more than flashing a light over the incorrect key.

(Manuscript received November 29, 1937)

References

1. Gilbert, R. W., A further study of the effect of non-informative shock upon learning, *J. Exper. Psychol.*, 1937, **23**, 333–350.
2. Hulin, W. S. and Katz, D., A comparison of emphasis upon right and upon wrong responses in learning, *J. Exper. Psychol.*, 1935, **18**, 638–642.
3. Silleck, Jr., S. B. and Lapha, C. W., The relative effectiveness of emphasis upon right and wrong responses in human maze learning, *J. Exper. Psychol.*, 1937, **20**, 195–201.
4. Tolman, E. C., Hall, C. S. and Bretnall, E. P., A disproof of the law of effect and a substitution of the laws of emphasis, motivation and disruption, *J. Exper. Psychol.*, 1932, **15**, 601–614.

Waits, J. V., The law of effect in the retained situation, *Arch. Psychol.*, 1937, No. **208**, 56 pp.

THE EFFECT OF 'SOMETHING HAPPENING' AFTER A RESPONSE *

BY FREDERICK A. COURTS

Stanford University

AND DEWARD WAGGONER

Reed College

In an attempt to explain the fact recognized by Thorndike (4) that rewards strengthen connections much more than punishments weaken them, Stephens (3) has presented experimental data which he interprets as evidence that "the mere fact that 'something' happens after a response tends to strengthen the underlying connection and that a rewarding something may add to the strengthening influence and a punishing influence detract from it." The influence of a rewarding 'something' is thus due to influence of the reward itself plus the influence of the medium through which the reward is presented. The influence of punishment is, according to Stephens, equal to the influence of the punishment per se minus the influence of the punishing medium. This hypothesis and the experimental data upon which it is based have been criticized by the senior author (1).

If Stephens' hypothesis is correct the following effects should obtain as the result of various conditions following a number of responses of the same type:

(1) A response followed by the word 'right' plus the flashing of a light should have a greater tendency to be repeated than does a response which is followed by only the word 'right.'

(2) A response followed by the word 'wrong' plus a flash of light should be more apt to be repeated than is a response which is followed by only the word 'wrong.'

(3) A response followed by a flash of light should show a greater tendency to be repeated than does a response which is followed by nothing.

* From the psychological laboratory of Reed College.

The present experiment was designed to test Stephens' hypothesis by determining the accuracy of the three preceding predictions.

Apparatus.—The apparatus was similar to that used by Stepehens. It consisted of a horizontal target tray, screened from the subject by a board 28-inches square. Near the base of the screen was a round opening large enough to accommodate the subject's arm. A cloth sleeve which could be pulled around the subject's arm by means of a draw string was fastened over the hole. On the experimenter's side of the screen were the target tray and two telegraph keys. One of these was connected in series with a buzzer fastened to the back of the screen. The other key was in circuit with a 32-candle power light, which was on the subject's side of the screen directly in front of his eyes. The entire apparatus was painted dull black.

Procedure.—The following directions were read by each subject immediately preceding the experiment:

> In this experiment you are to try to hit a certain part of a target. The target lies flat on the table and you are to try to hit it with a pencil. You will not be able to see the target because there is a screen between you and it.
>
> Each time you hear the buzzer you are to make one hit at the target and then quickly return your hand to the resting position.
>
> After some trials you will be told 'right' or 'wrong.' If the experimenter say 'right,' it means that you have hit the correct place. If the experimenter says 'wrong,' it means that you have hit a wrong place. After some trials you will not be informed of your success.
>
> At times the target will be shifted. Then you will have to start all over again. You will be notified by the experimenter on the occasion of each shift in the target.

The various conditions following the responses were 1, 'right' (R), 2, 'right' plus light (LR), 3, 'wrong,' 4, 'wrong' plus light (LW), 5, light (L), and 6, the control condition (C), in which the response was followed by neither the light nor verbal information. Each condition was presented eight times.

A set of sixty 8½-inches × 11-inches target sheets was made up for each subject. On each sheet there was a symbol indicating the nature of the condition which was to follow the first test hit recorded on this sheet. In addition there was marked on each sheet the number of practice trials which were to be presented before the test trial. This number, determined by chance, varied from two to five. The results of the practice trials were not recorded, since their only function was to keep the test trials irregularly spaced and to separate them temporally. The chance orders of conditions following the response and the number of practice trials were determined by shuffling cards, 12 at a time until 60 consecutive trials were prepared. A new series was constructed for each subject.

Having read the directions, the subject was seated before the apparatus with his arm extended through the opening in the screen. A soft black lead pencil was placed in his hand, and his hand was then guided to its resting position on a wooden block placed between the screen and the target tray. After giving a ready signal, the experimenter sounded the buzzer as a signal for the first hit. He continued to signal at five-second intervals until the indicated number of practice trials had been completed. The test sheet was then placed on the target tray and the signal given for the next hit. One second after this hit the particular condition called for on the test sheet was

presented. Four seconds later a signal was given for the next hit. The test sheet was then removed and signals were continued at five-second intervals until a total of eight hits had been completed. The experimenter then informed the subject that the target was being shifted. The procedure was then repeated until the sixty test sheets had been used.

The results of the first twelve trials were not included since during this preliminary period the subject was becoming familiar with the apparatus and technique. In this way eight completed tests sheets were obtained for each of the six experimental conditions. The deviation of the second hit from the first was measured in millimeters. A comparison of the values obtained in this way for each of the six conditions was taken as an indication of the relative strength of the tendency to repeat the response followed by that condition.

Subjects.—Results were obtained from 53 subjects, all of whom were undergraduate college students.

Results.—The average of the deviations of the second hit from the first for each of the six conditions is shown in Table I.

TABLE I

AVERAGE DIFFERENCE BETWEEN THE FIRST AND SECOND HITS UNDER THE SIX EXPERIMENTAL CONDITIONS

N = 53

Condition	Mean	S.D.	σ mean
R	14.5	6.7	.9
LR	14.7	6.8	.9
W	92.5	26.6	3.7
LW	91.5	32.0	4.4
L	50.9	24.8	3.4
C	64.9	27.1	3.8

These values represent the averages of the 53 subjects' mean deviations between the two hits on the eight test sheets used under each condition.

The differences between the means and the statistical significance of these differences are presented in Table II.

TABLE II

SIGNIFICANCE OF THE DIFFERENCES BETWEEN THE MEANS OF THE DEVIATIONS OBTAINED UNDER THE VARIOUS CONDITIONS

N = 53

Condition	Diff.	r	σ diff.	C.R.
LR–R	.2	.60	.8	.2
W–LW	1.0	.92	1.2	.9
C–L	14.0	.50	3.6	3.9
L–LR	36.2	−.09	3.6	10.1
LW–L	40.6	.06	5.6	7.2

The coefficients of correlation in this table were obtained by correlating the means of the distance in millimeters between the two pencil marks on the eight test sheets obtained under one condition with the means obtained under the other condition. On the basis of Stephens' hypothesis it was predicted that responses followed by the LR condition would show a greater tendency to be repeated in the succeeding trial than would responses followed by the R condition. It was further predicted that responses followed by the LW condition should be more apt to be repeated than those followed by the W condition. The results of the present investigation fail to substantiate either of these predictions.

The third prediction, that responses followed by a flash of light should tend more to be repeated than those followed by nothing, was fulfilled. This difference, having a critical ratio of 3.9, is not to be attributed to chance.

The fact that the light accompanied information of success and information of failure an equal number of times suggests that it was not apt to become a substitute for either. However, it has been shown by Hall (**2**) that in the absence of definite information of success or failure there is a tendency for human subjects to evaluate their responses as being right or wrong. Thus, the light unaccompanied by information of success or failure may have been interpreted by the subject as ambiguous information of the correctness of his preceding response.

On the other hand, it may be argued that the control condition of nothing happening after the response may have been interpreted in the same way by the subjects. If this is true the difference between the C and the L conditions remains unexplained.

Conclusions.—The small difference between the LR and the R condition, and the equally small difference between the W and the LW condition indicate that an additional 'something' happening after a response has little influence when the factor of information of success or failure is controlled. In the absence of such control the 'something' happening results in a statistically significant change in performance.

We therefore suggest that the influence of the light, when the factor of information of success or failure is uncontrolled, is due, not to the light itself, but to the informative role which it assumes.

In order to explain the fact that a response followed by a 'meaningless' stimulus shows a greater tendency to be repeated than does a response followed by 'nothing happening' we submit the following tentative hypothesis: In the absence of definite information of success or failure a 'non-informative' stimulus following a response in a trial-and-error situation tends to become an informative cue of success.

(Manuscript received November 19, 1937)

REFERENCES

1. COURTS, F. A., The alleged retroactive effect of visual stimuli subsequent to a given response, *J. Exp. Psychol.*, 1937, **20**, 144–154.
2. HALL, C. S., A repetition of Thorndike's experiments on improvement in the estimation of lengths, *J. Gen. Psychol.*, 1935, **9**, 238–241.
3. STEPHENS, J. A., The influence of punishment on learning, *J. Exp. Psychol.*, 1934, **17**, 536–555.
4. THORNDIKE, E. L., *The fundamentals of learning* (New York: Bureau of Publications, Teachers College, Columbia University, 1932).

SUBJECTIVE FLICKER RATE WITH RELATION TO CRITICAL FLICKER FREQUENCY *

BY S. HOWARD BARTLEY

From the Laboratory of Neurophysiology, Washington University School of Medicine, St. Louis

Several physiological studies involving stimulation of the eye (Bartley, **1**, **2**) have begun to indicate how the nervous mechanism of the retina forms the sensory message. The results show that the nervous system and not the photochemical activity of the sense-cells determines the flash rate necessary just to produce a uniform sensory state. This is of special significance since the opposite has been very commonly supposed. Theories of visual sensation have generally attempted to attribute as many as possible of the visual discriminatory capacities to the sense-organ itself (the eye). Logically the eye must possess many of these. Furthermore, many of these functions have been looked upon as the direct correlates of its physical and chemical properties themselves. Obviously, the immediate impact of the stimulus (light) is upon the photosensitive substances in the retina, and only as a result of this does something happen to set up nervous activity. Success in laying certain basic properties of vision to the photochemical mechanism would assure us of an accurate type of knowledge of the eye, for the principles of photochemistry are quite well known. This line of work has existed for some time, currently carried on by Hecht and his co-workers. They have been interested in how Hecht's hypothecated photochemical mechanism might account for the properties of visual sensation. A notable instance of this attempt is the case of the parallel between Talbot's law and the expected behavior of the photochemical mechanism (Hecht and Wolf, **4**). Talbot's law states that stimulation

* Work done under a grant-in-aid for Neurophysiology from the Rockefeller Foundation.

which very rapidly fluctuates in intensity will not be seen to flicker but will be seen as if the same quantity of stimulation were uniformly distributed in time. They have taken the parallelism to show that the photosensitive system accounts for the law and thus for the frequency at which the subjective fluctuations just disappear, known as critical flicker frequency (c.f.f.). We do not know that the two parts of the parallel quantitatively compare, much less that the one is the cause of the other.

Due to the fact that a nervous mechanism with properties entirely different from a photochemical one is interposed between the sense-cell and sensation, the logical possibility of this nervous system's determining c.f.f. exists. All that need be required of it in order that it perform this particular function is to fail to react with discrete responses to as rapid stimulus changes as can the photochemical system. The c.f.f. will be determined by the most slowly responding segment of the visual pathway, regardless of the parallelism shown by Hecht. The results of the recent experiments cited above not only show that the nervous part of the eye is this slow mechanism but indicate further organizational details of retinal function. However, these cannot be outlined here for lack of space.

Investigations on the *perception* of flicker might be expected to corroborate the physiological experiments already cited. For example, it is an impression easily gained by observers in flicker experiments that the quality and rate of the fluctuations as subjectively perceived just before the critical frequency is reached are about the same regardless of the stimulus intensity. Yet, when intensity is varied it changes the actual stimulus frequency required to make flicker disappear (c.f.f.). It is known that c.f.f. varies between the limits of about 4 and 65 per second. If the subjective flicker rate near c.f.f. does *not compare with* the c.f.f. throughout this range, it is corroboration for assigning to the neural mechanism the determination of the fusion point (c.f.f.). It is not yet apparent how this discrepancy could be accounted for by the properties of a photoreceptor

system, in which, if it directly determined sensation, each flash should have its direct sensory consequence at all flash rates below c.f.f. Thus the subjective rate would always be the same as the flash frequency. As has been said, we find this not to be the case.

Method

In order to study the subjective rate and qualities of flicker as it approaches its c.f.f., apparatus was set up providing two adjacent stimulus fields whose flash rates were different, though their ratio to one another was fixed. The intensity of one of the fields could be varied. This simply required a mirror system like that of the terrestriscope, into the two halves of which separate sources of flashing light were projected. The open-sector discs for controlling the rates were geared together, and their relative rates remained the same when their velocities were altered. This ratio could be easily altered by changing the number of blades on one of the discs. The ratios found quite suitable for our purposes were 1–1.2, 1–1.6, and 1–2.4. The intensities of the flashes were kept low so that even the maximum frequency dealt with could be low. The left field will be called A, and the right, B; their actual flash rates, A_a and B_a; and their subjective flash rates, A_0 and B_0.

Results

When the intensity of a flickering field such as A is varied, the subjective flicker rate A_0 changes, becoming greater as the intensity is reduced. This is made manifest by the use of the comparison field B whose intensity and actual rate are constant.

The possibility follows, then, that the subjective rates A_0 and B_0 may be matched even though A_a and B_a are different. This equation was made time after time to the observer's satisfaction by adjusting the intensity of A. To insure the validity of the judgments at the rates used (A = 5.2 to 8.25 p.s. and B = 8.36 to 19.2 p.s.), after A_0 and B_0 were equated, the absolute flicker rates were increased by increasing

the velocity of the discs to determine whether the c.f.f. of *A* and of *B* would be reached simultaneously, as they should be to establish this validity. With care in determining the A_0–B_0 equation, the flickers in the two disappeared virtually together. The flicker of *A* could be brought back by a slight shift of intensity. In the majority of the cases, A_0–B_0 equations were made at flash rates near 72 percent of the c.f.f. for the 1–2.4 ratio, 67 percent for the 1.6 ratio, and about 38 percent for the 1–1.2 ratio. When the chosen rates were too low, the discrepancy between A_0 and B_0 could not be overcome; it remained perfectly apparent that the frequency B_0 was greater than A_0. Even though A_0–B_0 equations could not be made at rates which were only small fractions of the c.f.f., the failure is not due to the flashes reaching an absolute slow rate at which they could be more accurately observed, that is, it is not necessarily due to the slowing down of events to do away with conditions for 'illusion.' The above test of the matching of c.f.f.'s of *A* and *B* by equating subjective flicker rate at rates considerably below the c.f.f. seems to show this.

Especially with the highest A_0–B_0 ratio, both a course and a fine flicker could be seen in *B* below the minimum A_0–B_0 equation point. It was as if the eye were responding unequally to alternate flashes, vigorously to one and feebly to the next. That such can happen has been shown by the electrograms of the retina by Granit and Thurman (**3**) and Bartley (**1**). From this it seems safe to say that here we have the sensory correlate of such electrograms. As the rate B_0 is increased, the impression of this dual type of flash vanished and the flicker became uniform, finer, and less vigorous. It is to be taken from the above that as the A_0–B_0 ratio is increased, the absolute rates of flicker have to more nearly approach the c.f.f. in order that A_0 and B_0 can be made equal. Or to put it in terms of intensity, the greater the differences between *A* and *B*, the more nearly the c.f.f. must be approached for an A_0–B_0 equality, which is the very thing to be expected.

Yet the general situation may seem to contain a paradox,

for will subjective flicker (at very low intensities) in which the c.f.f. itself is as low as 4 per second ever become rapid enough to match one at high intensity? Near-threshold intensities cannot be compared simultaneously with ordinary higher intensities, and the matter cannot be directly tested as for the higher intensities already described. But the observer's subjective estimate, even with the lowest intensities, is that the residual flicker just before the c.f.f. is reached is rapid. It is much more rapid than the flicker which exists when the intensity is raised to ordinary levels, while maintaining the same A_0 rate. For example, in a typical case the intensity was lowered to where the c.f.f. was 4.7 per second. The subjective flicker just before the c.f.f. was reached was rapid, but when the intensity was quickly raised to one which would require 22.5 flashes per second for the c.f.f., the flashes were very slow. However, the transition from the subjective high rate to the low is not as gradual as change in intensity may be.

Discussion

It has apparently been commonly assumed that the subjective rate of flicker follows the stimulus rate, but the evidence just presented shows this not to be the case. This means that for the conditions of high intensity under which the c.f.f. is extremely high, the last vestige of subjective flicker is little if any higher in rate than the subjective flicker occurring at very low intensities where the c.f.f. is very low.

If Hecht's photochemical-sensory-parallel theory is to be adhered to, these observations would have to be declared illusory, in order that they might be disposed of. But the burden of proof would rest on those classifying them as such. Even if taken as 'illusory,' a nervous basis for the observations, regardless of where, must be granted. The parallel between the behavior of the retinal electrogram and sensation strongly suggests that at least the major differential conditions for the discrepancy between flicker rate and flash rate lie in the eye. If the c.f.f. is determined by a nervous mechanism, rather than a photochemical one, it is to be expected that as

the c.f.f. is approached, subjective flicker would always be based on a sequence in the system not only the same in pattern, but in rate (a maximum). A combination of factors would be responsible for this, flash rate being only one of them, for which reason flicker and flash would not always keep pace. C.f.f. would be reached when the conditions that had caused this maximum rate had just been exceeded. In a photochemical system, two opposing processes (a 'light' and a 'dark' process) are assumed which on account of limits to their velocities may reach a balance. Intensity of flash is a factor in varying the velocity of the 'light' process, so that just before the balance or stationary state is reached, the rapidity of the reversals is not always the same, and in every case must follow the flash rate. Hence, in such a situation, flicker and flash should keep pace, which they do not do. It is this discrepancy which is determined by the properties of the nervous system.

We may suppose that under any conditions of flicker there are many fluctuations in the instant-to-instant number of retinal elements active. With vigorous stimulation the large fluctuations are seen as the flicker. If the stimulation is reduced, they become relatively less important and the seen rate will increase because the secondary fluctuations become apparent. Or if the flash rate is increased at any constant intensity, each flash is effective in activating fewer and fewer elements, and so in that way the rate and magnitude of the seen fluctuations are determined by the nervous organization. Even though the actual c.f.f. may be made very high, the seen rate of fluctuation will not continue to increase throughout the whole c.f.f. range, the only change occurring being the increased feebleness of the fluctuations near each c.f.f.

Prejudice as to the functioning of the photochemical system of the eye may be laid aside. The visual phenomena described here and in the previous papers (Bartley, **1**, **2**) considered as a mode of behavior aside from the particular case of the retina, are of a type of which the central nervous system is quite capable without the interposition of any

sense-organ at all between stimulus and effect. For instance, if the saphenous nerve is stimulated directly by repeated electrical shocks, certain muscles of the leg twitch repeatedly. At a given stimulus strength and at sufficiently low frequency, a single twitch follows each stimulus. If either *intensity* or *frequency* is increased, the muscles become 'fused' to a sustained contraction. Every stage of flicker, as well as flicker fusion itself, can be demonstrated with such a preparation in a fairly precise parallelism with the phenomena of visual flicker. There is every reason for assuming that the visual pathway exclusive of the photochemical receptor has at least as competent a fusion capacity as the skin-to-muscle reflex of the hind limb.

Summary

Flicker rate (subjective) and flash rate (objective) were shown to differ as critical flicker frequency is reached. This is demonstrated by the fact that flicker rate (with a constant flash rate) is different for bright and dim flashes, and also by the fact that the flicker rate near c.f.f. is about the same regardless of the flash rate and intensity.

These facts in themselves do not seem explainable on the basis of photochemical determination of the c.f.f. They do, however, fit in very well with other facts which have already been taken to show that the c.f.f. is neurally determined.

(Manuscript received November 13, 1937)

References

1. Bartley, S. H., Some observations on the organization of the retinal response, *Amer. J. Physiol.*, 1937, **120**, 184–189.
2. Bartley, S. H., The neural determination of critical flicker frequency, *J. Exper. Psych.*, 1937, **21**, 678–686.
3. Granit, R., and Thurman, P. O., Excitation and inhibition in the retina and in the optic nerve, *J. Physiol.*, 1935, **83**, 359–381.
4. Hecht, S., and Wolf, E., Intermittent stimulation by light. I. The validity of Talbot's law for *Mya*, *J. Gen. Physiol.*, 1932, **15**, 369–389.